An exploration of Environmental Ergonomics:
the case of restaurant kitchens in Durban

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DECLARATION

An Exploration of Environmental Ergonomics: a Case of Restaurant Kitchens in Durban

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DECLARATION

I, Sasi Gangiah hereby declare that the work presented in this research is my own and all sources have been duly acknowledged.

Sasi Gangiah

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ABSTRACT

Title: An exploration of Environmental Ergonomics: the case of restaurant kitchens in Durban

Several studies have raised concern that indoor environmental quality (IEQ) of commercial kitchens is not conducive to the well-being of kitchen workers as heat illness may be unreported in that industry. To comprehend the magnitude and severity of the threats to the workers in the industry it was necessary to evaluate the indoor environmental quality parameters-heat, ventilation and humidity, noise and lighting in kitchens, cognisant that with different kitchen loads offer different cuisines. A mixed method design was chosen for this exploratory case study. Questionnaire, interview schedule and structured observation instruments were developed for method triangulation using a purposive sampling technique.

Humans have an immense capacity to adapt physically, physiologically and psychologically to a broad range of environmental states. Human response to kitchen heat, indoor air quality, humidity, noise and lighting is influenced by a range of interactions such as worker demographics, context, environmental interactions and cognition. Variations in thermal tolerance are further intensified by ethnicity and cultural differences. Not withstanding, among the goals of occupational safety are health intervention for worker comfort to enhanced work performance. The study accordingly scrutinised theory in respect of relationship between individual differences and contextual components and factored these into controlled heat in work environment as well as other IEQ parameters. This exploration will add to knowledge of IEQ among restaurant owners and improve workers adaptation to kitchen environment which is beneficial to theories of productivity, worker satisfaction and overall well-being of workers.

It is anticipated that this study will help to raise attention to the implementation of appropriate intervention program to benefit foodservice workers, chefs, bakers, ergonomists, academicians and management.

Key words: IEQ, employee well-being, exploratory, triangulation, mixed-method

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ABBREVIATIONS

ARI-Acute Respiratory Infections

ACGIH -American Conference of Governmental Industrial Hygienists

ANSI- American National Standards Institute

ASHRAE-American Society for Heating, Refrigerating and Air-Conditioning Engineers.

AT-Apparent Temperature

ATT-Acquired Thermal Tolerance

BMR-Basal Metabolism

BGT-Black Globe Temperature

BOSH-British Occupational Safety and Health

BREEAM- Building Research Establishment Environmental Assessment Method

CCOHS-Canadian Centre for Occupational Health and Safety

CDC-Centre for Disease Control

CO_2-Carbon Dioxide

CO-Carbon Monoxide

CIBSE- Chartered Institution of Building Services Engineers

CRI-Color Rendering Index

CEN- "Comité Européen De Normalisation" (CEN) European Standardization Organization

CKV- Commercial Kitchen Ventilation

CFL-Compact Fluorescent Lamps

CASBEE- Comprehensive Assessment System for Built Environment Efficiency

COF-Cooking Oil Fumes

DA-Displaced Aggression

ET-Effective Temperature

EPRI-Electric Power Research Institute

EHS-Environmental, Health and Safety

EASHW-European Agency for Safety and Health at Work

EPA-Environmental Protection Agency

FDA-Food and Drug Administration

FCSI-Foodservice Consultants Society International

FFA-Free Fatty Acid GBCSA-Green Building Council South Africa

HA-Heat Acclimatization

HSA-Health and Safety Administration

HSE-Health and Safety Executive

HBM-Heat Balance Model

HAM-Heat Adaptive Model

HI-Heat Index

HDP-Hearing Protection Devices

HRI-Heat Related Illness

HVAC-Heating, Ventilation and Air Conditioning

HX-Humidex

IAQ-Indoor Air Quality

IARC-International Agency for Research on Cancer

IEQ-Indoor Environmental Quality

IGEM-Institution of Gas Engineers and Managers

IMC-International Mechanical Code

ILO-International Labour Organisation

ISO-International Organisation for Standardisation

LBNL-Lawrence Berkeley National Laboratory

Leq-Level-Equivalent

LEED-Leadership in Energy and Environmental Design

LED-Light Emitting Diodes

LFN-Low Frequency Noise

MCK-Minnesota Commercial Kitchen

NIHL-Noise Induced Hearing Loss

NIOSH-National Institute of Occupational Safety and Health

NWS-National Weather Service

NO-Nitric Oxide

NO_2-Nitrogen Dioxide

NIF-Non Image-Forming

OHSA-Occupational Health and Safety Act (2003)

OSHA-Occupational Safety and Health Act (2003)

OEL-Occupational Exposure Limit

PM-Particulate Matter

PeSI- Perceptual Strain Index

PAH-Poly Aromatic Hydrocarbon

PMV-Predicted Mean Vote

PPD-Predicted Percentage Dissatisfied

REL-Recommended Exposure Limits

RH-Relatve Humidity

RPM- Revolutions per Minute

SAD-Seasonal Affective Disorder

SBS-Sick Building Syndrome

SPL-Sound Pressure Levels

SANS-South African National Standard

SANAS- South African National Accreditation System

Sbtool- Sustainable Building Tool

TLV-Threshold Limit Value

TPC-Total Polar Compounds

TVOC-Total Volatile Organic Compounds

UL- Underwriters Laboratories

UFP-Ultrafine Particles

WBGT-Wet Bulb Globe Temperature

WHO-World Health Organization

CHAPTER ONE
INTRODUCTION

1.1 Preamble

Over a decade ago, Chapanis (2004: 1) claimed that the present-day ergonomics is not robust enough to cope with the several significant differences found among the people of the earth. More recently, Sanjog *et al*. (2013: 507) observed that there is an absence of attention to racial and topographical diversity, personal variances and flexibility while planning any indoor workplace facility. Formulation of standards specific to particular industries, locations and countries can result in optimal design for human well-being, realising the goal of ergonomics on a global scale. Eagles and Stedmon (2004: 440) were early to identify that the main aspects of indoor ergonomics in kitchens include temperature, noise, lighting, ventilation and humidity. The idea of investigating commercial kitchen compliance with ergonomic principles was born to the researcher. This exploratory research endeavour, therefore, investigates the impact of common heating, lighting, acoustics, ventilation and air-conditioning on indoor environmental quality and the well-being of food production workers.

Given that a commercial kitchen is a complicated environment (Yuan *et al.* 2013: 61), there are multiple components of an indoor environmental system that do not always interact in unison but by design or by chance (Livchak *et al.* 2005: 748). The current study will uncover vital components in kitchen products and workplace designs that will enhance usability suited to those working and using the area. Generally, and more specifically in commercial kitchens in Durban, South Africa (SA), kitchen worker ethnicity, individual differences, geographic diversity and adaptability remain unexplored research areas. A limited number of reports are available on environmental parameters of commercial kitchens. Eagles and Stedmon's (2004: 440) pioneering study is the basis of the evaluation of indoor environmental quality (IEQ) of commercial kitchens. Problems with IEQ parameters such as heat, noise, lighting and indoor air quality (IAQ) of a building have a direct bearing on the well-being and output of the occupants (De Giuli *et al*. 2012: 335); therefore, the food service industry needs to provide a good quality of work-life to attract and retain workers (Kandasamy and Ancheri 2009: 328).

1.2 Significance of the study

The present research attempts to contribute to the gaps in knowledge of commercial kitchen environmental ergonomics by adding to the small pool of available empirical work on this issue. In its theory-building endeavour, the study has the potential to improve kitchen IEQ and inform on optimal environmental conditions for local kitchen personnel that will positively influence their health status. IEQ is the collective conditions inside a building and refers to access to daylight, acoustic conditions, lighting, thermal comfort and indoor air quality are affected by moisture. The study may also promote the creation of physically healthy environments for food service workers in South Africa (SA) by assisting policymakers for example, the SA Department of Labour to amend policies that regulate standards for kitchen environmental ergonomics.

The findings are expected to be useful in the field of environmental ergonomics in the food service industry. This research will provide insight into the criteria that will support to evaluate the indoor environmental condition and the well-being of kitchen staff in commercial kitchens. The relevance of the criteria will be supported with a framework of the physical environment and the human aspect, with a focus on the demographics of food service workers. Therefore, a platform to set standards regarding the specific requirements for the levels of temperature, humidity, noise and light shall be offered.

The research will add to the knowledge of the cause and effect relationship between five study parameters and human responses in a commercial kitchen and develop a viable theoretical framework. The empirical recommendations will assist in the area of food service management to draw attention to incorporate a proper intervention program to improve the kitchen atmosphere and maintain worker retention. It is anticipated that the resulting framework will serve as the foundation for developing an environmental quality policy and standard operating procedures for commercial kitchens. Hence, this exploratory study can serve as a springboard for further research into better understanding, modeling, and extrapolation among a variety of hot workplace environments for human well-being in kitchens.

Recommendations emanating from this research may also assist the food production sector locally and in locations that enjoy similar working environments. In South Africa, it is acknowledged that ergonomics is important but there seems to be a major gap in terms of understanding and implementation which this research attempts to clarify by contributing to the formulation of future ergonomic regulations that will assist employers in addressing ergonomic risk factors. The Department of Employment and Labour under Occupational Health and Safety Act, 1993 have included Ergonomics Regulations, 2019.

1.3 Research aim and objectives

The food service business is disadvantaged by poor ergonomics (Gigstad 2002: 9). Schwarz (2018: 2) states that the issue of ergonomics in commercial kitchen planning is here to stay as it is a manufacturing environment for producing meals, albeit on a small scale. Proper ergonomic conditions are necessary to prevent discomfort and fatigue (Wellright 2018: 4). Considering that ergonomics is a key part of the planning process, the indoor climate in a large-scale kitchen has a significant impact on the kitchen's ergonomics (Schwarz 2018: 2). Hence, in the context of restaurants, the health and safety of workers are vital, meaning that environmental ergonomics must be given due attention.

Catering kitchens are multifaceted workplaces with exposure to a harsh work environment. On the one hand, Hima Bindu and Reddy (2016: 1320) find that kitchen workers satisfied with workspace features such as lighting, access to natural light, ventilation rates, and acoustic environment have better productivity. On the other hand, Qiang and Chow (2007: 333) state that acoustics, heat, lighting and higher levels of noxious emissions in the kitchen air are serious threats to the well-being of staff. These threats that arise from deficient environmental ergonomics have been reported in studies by Simone *et al.* (2013: 1002), Ramesh and Manikandan (2015: 472), Hima Bindu and Reddy (2016: 1337), Park *et al*. (2017: 477), Kabir (2019: 4) and Alam *et al*. (2019: 6). These studies have measured individual parameters to include heat, humidity and airflow that reflect thermal comfort. Marć *et al*. (2018: 2072) add that the environmental factors, such as humidity, radiant heat and airflow, significantly influence the comfort of work and well-being of workers in commercial kitchens.

Additionally, perceptions of comfort or discomfort differ amongst individuals, and researchers such as Rajasekar and Ramachandariah (2014: 1) argue that factors such as age, thermal anticipation, economic status and familiarity with warm conditions induces a person's awareness to comfort. Accordingly, Frontczak and Wargocki (2011: 922) remark that aspects unrelated to the IEQ could significantly affect the occupants' perception as building occupants endure numerous environmental influences simultaneously, and interactions among these can affect their perception.

Adding to the multifaceted influences are the external environmental parameters that influence internal kitchen conditions. The gap in the literature was identified by Torresin's *et al.* (2018: 535) assertions of a lack of available information on how interacting factors affect the attainment of the overall comfort in indoor environments.

The present study is in subtropical Durban known for high humidity causing discomfort (Conradie 2012: 3). It is essential that a working environment increases productivity through noise reduction, better lighting, and a better indoor environment (Clements-Croome 2006: 35). Despite requirements of technical criteria for each environmental aspect being met separately, it does not necessarily entail a complete satisfaction for the environmental ergonomics of commercial kitchens. Hence, it is imperative that all five parameters are measured simultaneously in commercial kitchens to study their impact on subjective responses.

In light of the above, the following aim and objectives are tendered:

1.3.1 Aim

To investigate the impact of heat, lighting, acoustics, ventilation and humidity on indoor environmental quality and the well-being of food production workers.

1.3.2 Objectives

1.3.2.1 To examine indoor airflow, humidity, lighting and acoustics in restaurant kitchens.

The assessment of environmental ergonomic parameters in commercial kitchens in Durban would establish the current trends in Durban kitchens such as cooking appliances, the design of the workstation, worker density/occupancy, and variable environmental conditions during business hours.

1.3.2.2 To determine the thermal environment, heat stress amongst food production workers using gas and kitchen appliances.

Electricity and gas are common fuels used in commercial kitchens that influence heat and humidity in the food production environment. Although kitchen workers should be familiar with these fuels, attitudes can influence comfort levels in the work environment. Fuels potentially affect worker experience and environmental satisfaction with regard to heat, noise and IAQ.

1.3.2.3 To investigate the perception of food production workers' adaptability to selected indoor environmental conditions.

An **e**xamination of the adaptability of local food production workers which may be influenced by ethnicity and physique to selected indoor kitchen environmental quality (IEQ) conditions. Demographic variables such as age, gender, BMI and physical activity are examined to elicit the fitness of workers.

1.3.2.4 To compose indoor environmental criteria for design of restaurant kitchens in Durban in respect of indoor airflow, humidity, thermal environment, lighting and acoustics.

The study will elicit empirically-based guidelines that will contribute to the advancement of environmental ergonomic practices in commercial kitchens in subtropical locations for the well-being of food production workers. Standardised international methods apply to an office environment but not suitable for commercial kitchens.

1.4 Study area

South Africa is located at the southernmost region of Africa, with a long coastline that stretches more than 2,500 km (1,553 miles) and along two oceans (the South Atlantic and the Indian). Durban is a South African city found in KwaZulu-Natal. Durban is 16m above sea level. The climate is warm and temperate. The Köppen-Geiger climate classification is Cfa (humid subtropical). The average annual temperature is 20.9 °C (69.6 °F) in Durban. The rainfall is around 893 mm (35.2 inch) per year. The average wind speed in Durban is more than 11.5 miles per hour (18.5km/h).

In terms of race, Durban has over 51% of residents comprising of Black Africans. Nearly one-quarter of the population is of Asian origin, while 15.3% are of European (White) origin, and 8.6% are designated as Coloured (mixed race). The largest ethnic group are the Zulus.

The selected restaurant kitchens were predominantly located in Westville, Glenwood, Durban North, Sunningdale, Glenashley, Umhlanga and Hillcrest areas of the Durban Municipality (Figure 1.1).

Figure 1.1 Map of Durban and surrounds (https://www.portfoliocollection.com/map/kzn-durban)

In respect of commercial kitchens, there is no empirical data available on type, classes and forms of these in Durban. However, several types of restaurants are observable in the study area. These include Italian, Chinese, Thai, Zulu, Indian, Mozambican and Portuguese cuisines; Chicken Tikka centres, kiosks, cafe´s, coffee shops, bars, doughnut shops, restaurants, roadside eateries, taverns and casino clubs. Further to proprietor owned restaurants, the study area includes food franchises such as fried chicken, seafood, pizzerias, burger centres, subs, grilled chicken and sushi bars.

1.5 Overview of theoretical framework

The conceptual research model for this study incorporates heat, lighting, noise, ventilation and humidity as factors that influence occupant's comfort or discomfort in the workplace (Figure 1.2).

Indoor Environmental Quality (IEQ) has an affirmative association with workers' comfort. Indoor environmental quality can be defined as "the measurement of the key parameters affecting the comfort and well-being of occupants" or the "elements to provide an environment that is physically and psychologically healthy for its occupants" (Garnys 2007: 1). IEQ includes the integrated physiological and psychological influences of thermal, acoustic and luminous environments and air quality on occupants (Jacklitsch *et al.* 2016: 23).

Consistent with Nimlyat *et al.* (2017: 144-145), thermal comfort is measured by four variables such as satisfaction with temperature, airflow, relative humidity (RH), and overall satisfaction with thermal environment.

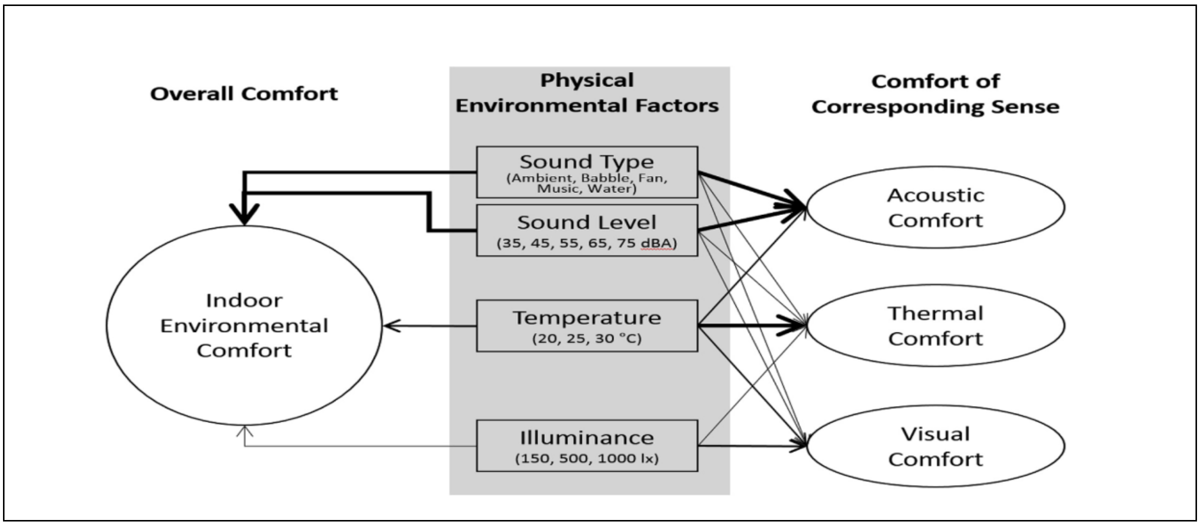


Figure 1.2 Indoor environmental comfort attributes framework (adapted from Yang and Moon 2019: 630)

The measurement of acoustic comfort consists of elements such as satisfaction with noise, sound privacy and overall satisfaction with acoustic environment. Visual comfort is measured using four variables such as satisfaction with natural light, artificial light, amount of light and overall satisfaction with visual environment.

1.6 Overview of literature

The kitchen work environment of the food service industry is considered severe on health due to a hot environment, in addition to irregular working hours. Previous studies by Haruyama *et al*. (2010: 135) and Matsuzuki *et al.* (2011: 605) report that work in commercial kitchens is performed under high ambient temperatures.

Kitchens can become extremely hot over the course of a long shift; hence, adherence to Occupational Safety and Health Act guidelines in a kitchen with regard to thermal conditions can assist in employees feeling satisfied (Webstaurant Store 2018: 1). Not surprisingly, among different indoor environmental parameters thermal comfort is given higher importance than visual, acoustic and air quality (Sanjog *et al.* 2013: 508). Lestinen *et al.* (2020: 631) comment that indoor thermal conditions and comfort are important factors in human well-being.

Where the temperature and humidity are both high, humidity emerges as the potent force for discomfort (Alshaikh *et al.* 2014: 1). Consequently, heating and cooling systems are devised to reduce humidity to improve the efficiency of work processes in hot climates (Alshaikh *et al.* 2014: 1).

Sufficient ventilation and airflow are moreover, crucial elements in the thermal comfort of a workplace; the general principle being that effective and suitable provision should be made to ensure that every enclosed workplace is ventilated by a sufficient quantity of fresh or purified air (Eagles and Stedmon 2004: 441).

Livchak *et al.* (2005: 748) accordingly posit that a commercial kitchen is an intricate environment where numerous mechanisms of a ventilation system including extractor, chilled air vents, and makeup air systems function together constantly but not in harmony. This prevents kitchens from being cool and comfortable and hampers productivity, staff retention, and subsequent profit for a catering business.

Kitchen worker health is also threatened. According to Ghaffarianhoseini *et al*. (2018: 100), poor IAQ can increase respiratory diseases, sick building syndrome (SBS) symptoms and allergies. Chinthala *et al*. (2020: 46) posit that emissions of indoor air pollutants like volatile organic compounds (VOC) have a direct bearing on people's comfort and health. The importance of a well-designed ventilation in the kitchen is reiterated by Kosonen's (2006: 26) review of literature on cooking and lung cancer. The author observes that concerns over the IEQ have increased during recent years because of knowledge about the significance of thermal conditions, IAQ on health, comfort and productivity of the workforce. Carbon dioxide (CO_2) and carbon monoxide (CO) levels in the kitchens indicate the performance of Heating, Ventilation and Air Conditioning (HVAC) systems and quality of air (Kosonen 2006: 26).

According to Akbari *et al*. (2013: 2), improvement in the direct and indirect influences of light has decreased vision disturbance, neck and shoulder pain, eye fatigue and headache. Inappropriate lighting such as neon lights often caused annoyance, eyestrain and fatigue (Sanjog *et al.* 2013: 510).

Similarly, noise levels may be considered to directly or indirectly affect physical and psychological aspects; managing noise will have a constructive effect on workers and their output (Akbari *et al.* 2013: 4). Potential dangers include acceptable shouting in kitchens, equipment noise and extraction mechanisms as per European Agency for Safety and Health at Work (EASHW) (2008: 120). Cumulative and repetitive exposure to high-intensity noise levels and long period of interaction with noise levels beyond the permissible exposure limit may aggravate the development of hearing loss (Sayapathi *et al.* 2013: 1).

Notably, the human ear is most sensitive to the range of frequencies used in the human voice; humans can be distracted by a boisterous crowd, yet tolerate high levels of sound coming from trains as background noise (Boduch and Fincher 2009: 6).

The consequences of poor ergonomics go beyond the loss of performance and workplace usability (Gigstad 2002: 13). Geekie (2016: 96) asserts that well-planned workspaces provide physical comfort and contributes to well-being within the work environment. There are not many firm ergonomic strategies, distinct from other workplace designs, to support the safe design and use of kitchens (Eagles and Stedmon 2004: 441).

1.7 Overview of research methodology and data sources

While research begins with the process of inquiry (Leedy and Ormrod 2010: 32), the systematic processes of data collection and analysis in any research endeavour is key to the development of knowledge.

1.7.1 Research Design

This research is an exploratory case study on environmental ergonomics in different kitchen cases forming the investigation. According to Yin (2014: 4), a case study method is applicable when research involves an extensive and detailed depiction of phenomena, the author adds that a multiple case study enables the researcher to explore differences within and between cases (Yin 2014: 60). The study utilises chiefly quantitative techniques and some qualitative data. The aim of quantitative research is to assess objective data while qualitative research deals with subjective data produced by participants. Saunders *et al.* (2009) posit that it is essential to triangulate multiple sources of data as a key strength in the data-gathering process. Readings from test instruments are used to cross-check results, as are the workers' opinions based on findings, interviews and questionnaires. The design was cross-sectional where the researcher measured the outcome and the exposures in the study participants at the same time (Setia 2016: 261). The sample frame comprised of eThekwini Municipality licensed restaurant kitchens.

The primary data was gathered by means of scientific test equipment illustrated in Table 6.5 (page 131) and social research tools such as questionnaire, interview schedule and observational checklist. The former provided objective measures of environmental ergonomic design data. Rajasekar and Ramachandraiah (2010), Matsuzuki *et al.* (2013), Simone *et al*. (2013), Nassiri *et al.* (2013) and Akbari *et al.* (2013) have found success in the use of one or more of the aforementioned equipment in their studies. More recently, Zuhaib *et al*. (2018: 12) adopted these for physical parameter measures of IEQ variables namely, indoor air temperature (°C), RH (%), mean radiant temperature (°C), air velocity (m/s), illumination (lux), Carbon dioxide (CO_2) parts per million (ppm) and noise level (dB). The field study was conducted in the different areas of the selected kitchens during the summer months of January to March 2017 during the daytime.

A semi-structured interview schedule was administered to food production workers, which comprised a series of open-ended questions according to themes. The interviews of workers were conducted concurrently with the field measurements. The questionnaire was distributed to the kitchen managers and head chefs by the researcher. The third data collection tool concerning kitchen layout and ergonomic design for all the kitchens was evaluated by non-participant observation. Observation can be valuable, especially when photographs are taken, which increases the reliability of observations (Heinzerling *et al.* 2013: 32).

Questionnaire data and test equipment measurements were analysed using SPSS version 25. Data analysis was undertaken using descriptive and inferential statistics. Method triangulation was used with the quantitative and qualitative data obtained from the interview schedules, questionnaires and observation schedules were compared. The statistical tests used for interpretation of data were chi-square analysis, factor analysis, regression and cross-tabulations. Correlation was used to assess reliability with scores being closer to 1.0 considered more reliable. Multiple logistic regression models were used to define the relationship between multiple variables. The semi-structured interview schedule and the questionnaire were pilot-tested prior to use.

1.8 Validity and reliability

Reliability means consistency and validity means accuracy (Adams and Lawrence 2018: 69) as both are critical factors in research and are the foundations of good research relevant measures are described in section 6.7. Validity concerns what an instrument measures and how well it does so (Mohajan 2017: 58). Reliability refers to the ability, consistency or dependability of an instrument. The test equipment was calibrated by the supplier to give accurate readings. Internal consistency of the questionnaire and structured observations was estimated by Cronbach's alpha. According to Yin (2013: 115), one of the best ways to enhance reliability is observation; however, it requires multiple observations at different times.

1.9 Anonymity and confidentiality

According to Yin (2011: 197), anonymity is important to protect the real case and its real participants. The participants should have no doubt that their anonymity is ensured in the future (Welman *et al.* 2005: 196). There was no deception in the study and pseudonyms were used in results and discussions. A unique identifying code was issued to all participants so that no one outside the research team would be able to identify them.

1.10 Ethical considerations

Ethical clearance was obtained from the Durban University of Technology to conduct the study. Conducting ethical research is more than simply doing the right thing (Mandal *et al*. 2011: 1). The researcher built a position of trust with the gate keepers and food service workers by frankness and honesty and, individually approaching them to obtain their consent. The participants were informed of the topic, procedures, risks and benefits of participation prior to consenting to the study. The researcher treated respondents with respect which indicated that the interviewer is interested in them as individuals and accepted their uniqueness.

1.11 Structure of study overview of chapters

This study contains eleven chapters. Chapters One to Five are all part of the Literature Review. The outline of the thesis is presented in detail, below:

Chapter One: Introduction

This chapter is an outline of the research undertaken and offers a context to the theme being explored. It explains the impact of environmental parameters that influence internal kitchen conditions. It comprises of the aims and objectives, rationale behind the study and the research approach engaged to find explanations to the concerns.

Chapter Two: An overview of the thermal environment in commercial kitchens.

This chapter reviews the literature relating to the heat in kitchens which is affected by ventilation and humidity factors

Chapter Three: An overview of the ventilation and humidity in commercial kitchens.

This chapter reviews the literature relating to ventilation and humidity factors affecting the thermal environment in commercial kitchens.

Chapter Four: An overview of noise in commercial kitchens.

This chapter focuses on a review of the literature on the influence of noise in the kitchens and its effect on food production workers.

Chapter Five: An overview of lighting in commercial kitchens and interrelationship between key variables.

This chapter focuses on a review of the literature on the effect of lighting in the commercial kitchen and its effect on food service workers and discusses the impact of five parameters on each other.

Chapter Six: Methodology

This section delivers a thorough explanation of the procedures used. It offers research design, sampling techniques, method triangulation and data exploration, selection of kitchens, selection of research tools, data collection techniques, approaches to enhance validity and reliability of the observed research.

Chapter Seven: Data analysis of heat and thermal comfort in commercial kitchens

This chapter presents the empirical results of the quantitative and qualitative study. The quantitative study will be analysed using SPSS version 25 and thematic content analysis will be used to present the qualitative analysis of the thermal environment in kitchens.

Chapter Eight: Ventilation and humidity in commercial kitchens

This chapter presents the observed outcomes of the quantitative and qualitative study on the effect of ventilation and humidity on the discomfort level of food service workers.

Chapter Nine: Data analysis of noise in kitchens

Results are interpreted and the significance of noise in commercial kitchens is discussed.

Chapter Ten: Data analysis of lighting in kitchens

Outcomes are construed and the implication of lighting in commercial kitchens is discussed.

Chapter Eleven: Conclusion and recommendations

This chapter summarises the main research findings and charts a way forward with recommendations to improve the working environment of kitchen workers.

1.12 Conclusion

The IEQ considered satisfactory by a particular occupant group may not be suitable to another. According to Kim *et al.* (2013: 245), several individual and psychosocial aspects beyond environmental concerns also influence occupants' awareness of the quality of an indoor environment. The chapter summarises the core findings to be inspected, make final deductions based on the examination and clarification of data and recommends how to improve environmental ergonomics in kitchens for the well-being of kitchen workers. Although the study was confined to the city of Durban, the findings are of general relevance to almost all commercial kitchens in South Africa and countries that enjoy subtropical climates.

CHAPTER TWO

HEAT AND THERMAL COMFORT

2.1 Introduction

The preceding section discussed the motivation for this research and presented an outline of the study to explore environmental ergonomics in restaurant kitchens in Durban with reference to kitchen conditions of heat, lighting, acoustics, ventilation and humidity. This chapter will commence with a discussion of the Heat Balance Model (HBM) and a more recent Heat Adaptive Model (HAM) on the human ability to cope with heat that has led to changes in world standards regarding indoor thermal comfort. The chapter will conclude with an examination of the effect on thermal comfort of individual factors such as age, gender, fitness, acclimation, behavioural modification and ethnicity.

The two fundamental approaches to facilitate the examination of thermal comfort (Fanger 1986; Nikolopoulou and Lykoudis 2006 and Alexandru *et al*. 2016) apply to all indoor work environments, including commercial kitchens. The discussion that follows will present each of these approaches separately and highlight the relevance to kitchen environments.

2.2 Heat Balance Approach

The approach in the assessment of thermal conditions is based on the heat exchange between a human body and the surrounding environment and assumes that occupants are passive, and have no influence on their heat environment condition (de Dear 2004: 32). The Predicted Mean Vote (PMV) advanced in Fanger's (1970: 4) formative work best explains the HBM. The classic Steady State model predicts the mean thermal sensation of a group of people and their respective percentage of dissatisfaction with the thermal environment. Whilst the measure may be useful in kitchen design, personal differences make it difficult to specify a thermal environment that will satisfy everybody (Fanger 1970: 244). ISO 7730 "acceptable thermal room climate" is reasonable for 80 % of persons. The author further claims that a percentage of the occupants can always be expected to be dissatisfied, and this is termed as Predicted Percentage Dissatisfied (PPD).

The ergonomic environment across commercial kitchen varies. Initial investigations by Kempton and Lutzenhiser (1992: 1) demonstrate that the assumption of universality disregards important ethnic, climatic, social, and contextual dimensions of comfort, leading to an overestimation for air-conditioning. Brager and de Dear (1998: 1) later claim that American Society for Heating, Refrigeration and Air conditioning Engineers (ASHRAE) and International Standard Organisation (ISO) standards were initially applied uniformly through space and time and regarded as unanimously appropriate across all building types, climate zones and populations. Qui *et al*. (2020: 984) report that criteria for the evaluation of thermal comfort (ASHRAE Standard 55, ISO 7730) are used universally for all people irrespective of their ethnicity, nationality or country of origin. Hansen *et al*. (2013: 5) further raise the neglect of the effect of the interaction between climate and ethnic diversity. Qiu *et al*. (2020: 984) lament that ASHRAE Standard 55-2013 recognises that there is a variation in thermal comfort during winter and summer within the same geographic area, but it does not reflect on the dissimilarities in thermal preference of people of diverse ethnicities. Ilardo and Nielsen (2018: 77) claim neglect of the human ability to adapt to extreme environmental conditions. However, in the context of the HBM, Nicol and Roaf (2017: 145) found that the ASHRAE considered people to be comfortable if room temperatures were kept within a narrow range of 20 °C to 24 °C. The authors were critical of the lack of consideration of the behavioural, attitudinal or psycho-physiological aspects of human interactions with each other, the buildings, and the management of environments to sustain individual comfort.

International comfort room temperature ranges from 20 °C to 24 °C inside buildings according to the European Standardization Organization "Comité Européen de Normalisation" (CEN) and ASHRAE. The more extreme the climate, the larger the HVAC plant needed to target these temperatures in buildings (Nicol and Roaf 2017: 145) and the HBM considers opening windows unnecessary, triggering in downstream impact on IAQ and quality of life of the building occupants. Roaf (2020: 1112) asserts that buildings should have at least a few operable windows and habitable in natural ventilation mode. Ghaffarianhoseini *et al*. (2018: 104) report that the consequent effect of SBS symptoms and health inside buildings in the United States (US) results in an average office worker taking short-term sick leave. Nicol and Roaf (2017: 145) additionally criticise the possible zeal for energy-saving amongst building designers that fail to give due recognition to the impacts of poor ventilation. It seems that the HBM is applicable in a narrow temperature range in office buildings, however, commercial kitchens have much higher temperatures.

From another line of investigation, Simone *et al.* (2013:1014) explicitly state that the standard PMV/PPD index for thermal comfort used in workplace environment cannot be practical in commercial kitchens due to the combination of high activity levels, ambient and radiant temperatures. Hence, the HBM model is irrelevant to commercial kitchens. Contrary to Simone *et al*. (2013), Rahmillah *et al*. (2017: 1) propose the use of psychometric charts to assess the comfort zone in residential kitchens. Kajtar *et al*. (2005: 1) studied thermal comfort in kitchens and Sajedifar *et al.* (2017: 4) report on an Iranian hospital kitchen with PMV index. Studies have been conducted using PMV/PPD index or psychometric charts that corroborate results obtained by Witterseh *et al.* (2002: 1083).

When values exceed the ISO recommendation of 10 % for PPD, thermal discomfort was a common feature (van Hoof 2008: 184). Arens *et al*. (2020: 524) criticise that Section 5 in ASHRAE Standard 55 is steady-state and does not relate to a change in an individual's experience due to movement or activity level. This implies that PPD is invalid for kitchen workers who seem to be constantly moving while working in kitchens. Consequently, temperature perception can be overestimated by 2.1 °C and underestimated by 3.4 °C. This is due to a decline in the occupants' psychological dimensions and socio-cultural aspects (Rupp *et al.* 2015: 195). Socio-cultural aspects influence heat-stress perception in the workplace according to Messeri *et al*. (2019: 9). Indraganti *et al.* (2014: 39) report that the PMV miscalculated the Actual Sensation Vote (ASV) of the residents in apartments in India. Therefore, this model fails to demonstrate reliable and accurate conclusions for indoor thermal comfort (Yang *et al.* 2015: 290). Wang and Hong (2020: 1) criticise ASHRAE Standard 55 and ISO Standard 7730 that uses the PMV/PPD model or the adaptive comfort model that is based on a small sample or obsolete data.

Even after the latest rounds of thermal comfort standard revisions, Fanger's (1970) PMV model is still the authorised instrument to calculate thermal comfort (van Hoof 2008: 184). The author criticizes the PMV model on the ground that the three central set of the ASHRAE 7-point scale of thermal sensation appears to be not completely valid. He also states that it is impossible to predict thermal comfort for individuals exactly, and irrational to presume that all individuals to be satisfied within a centrally controlled environment, even when the thermal conditions meet present criteria. The author's findings lead to the adaptive model and cause an important paradigm shift away from the HBM for the aged. As HBM is based on PMV, it is unsuitable for calculating thermal comfort in commercial kitchens. Forcada and Tejedor (2020: 212) report that PMV/PPD for elderly are inaccurate when compared to HAM. Similarly, Kulve *et al.* (2020: 216) find that the PMV model for children seem to experience warmer thermal sensations in school than actually experienced and there is an apparent inconsistency between how thermal comfort is perceived by adults and youngsters.

Furthermore, Cheung *et al*. (2019: 205) conclude that the precision of PMV in forecasting observed thermal sensation was low (34 %), which means that thermal sensation is erroneously predicted by 60 %. Furthermore, there is a need to advance precise thermal comfort models as ventilation strategies, building types and weather influenced the PMV/PPD accuracy (Cheung *et al*. 2019: 205).

2.3 Heat Adaptive Model

Unlike HBM, a heat adaptive approach assumes that occupants are active and adapt to the thermal environment. As per Babu and Suthar (2020: 141), several elements affect thermal comfort like behavioural and cultural aspects, space layout, personal control, thermal experience and preferences. One of the extrapolation of the HAM approach is that individuals in warm climate zones prefer warmer indoor temperatures compared to those living in colder climate zones (Nikolopoulou 2011: 1552).

Adoption of an adaptive model allows occupants to feel comfortable in a wider range of conditions than those in the PMV index (Frontczak and Wargocki 2011: 925). Thermal comfort is also influenced by individual variations in attitude and social factors (Djongyang *et al.* 2010: 2627). Nikolopoulou (2011: 1552) adds that behavioural, physiological and psychological adaptations of people are based on familiarity with heat, time of year, weather conditions, culture, and lifestyles that include building design, building function, genetic factors and acclimatisation. Sanjog *et al.* (2013: 508) observed an increase in productivity and contentment of the occupants resulting from improved thermal comfort and workers' perceived ability to control the environment. This perception could be due to a psychological influence (Luo *et al.* 2016: 63). Nicol (2020: 18) established that the thermal comfort experiences of residents of one city in a nation could be drastically dissimilar with diverse habitations or climatic zones and hence better to recognize the actual thermal preference for every major ethnic group.

It is clear that HBM discourages natural ventilation while HAM enables natural ventilation; there are, nonetheless, International Comfort Standards for both and these are presented later in this chapter. Frontczak and Wargocki (2011: 925) point out that there are differences in thermal acceptability of workers in an air-conditioned building who are less tolerant than occupants of naturally ventilated building of the indoor thermal environment. Holzer and Stuckey (2020: 1044) suggest that the building designers need to widely apply the adaptive comfort scale in naturally ventilated buildings.

According to Zuhaib *et al*. (2018: 4), physical and personal variables affect thermal sensations. The personal variables are clothing insulation and activity level. The authors add that the human body's physiological and psychological responses to the environment are active and incorporate various physical phenomena that interact with the space including heat, humidity, visual comfort and acoustics. Van Hoof *et al*. (2017: 123) report that elderly were sensitive to variations in their thermal environment and moved around the house and used internal doors to regulate air movement.

Absence of local discomfort such as draft, lack of too high-reflected heat asymmetry and absence of high vertical temperature differences can provide thermal comfort to workers. The comfort temperatures in the HAM is much wider across. People adapt to the temperatures within buildings, and they adapt the buildings to suit their thermal preferences (Zuhaib *et al*. 2018: 4). However, Cheung *et al*. (2020: 782) propose that attaining a high occupant satisfaction for certain IEQ factors is more difficult than other factors. Indraganti (2020: 840) finds that Asian women are more likely to be dissatisfied with thermal comfort perception, IAQ, lighting and noise level than men; an attitudinal change in the design of personal controls for women can enhance their satisfaction for various environmental parameters.

Rajasekar and Ramachandraiah (2010: 1) argue that factors like age, thermal expectation, economic status and experience with thermal comfort play a significant role in determining comfort perception. Rissetto *et al*. (2020: 266) verify that previous experiences in the hot environment affect thermal expectation, attitudes and values towards technology such as a ceiling fan may impact on behavioural adaptation. According to Kenawy and Elkadi's (2013: 1) study in Australia, thermal comfort is directly related to the tourists' attitude and behaviour in outdoor places. The authors add that tourists, having a variety of cultural and climatic backgrounds, as well as their physical, physiological and psychological adaptation have also proven to have a significant influence on their thermal comfort**.** Guevara *et al*. (2020: 248) find that students react to heat by the use of comfortable clothing, experience of the climatic conditions, and expectations that help to develop an adaptation to the local environment.

Similarly, simulated studies by Messe *et al.* (2004: 19), in South Africa, of male and female subjects from major ethnic groups found that the best performance for many tasks was in an environment with an air temperature of 32 ˚C (range of 20 ˚C to 38 ˚C) and RH 25 %. Subjects, however, preferred temperatures between 20 ˚C to 23 ˚C. Sanjog *et al*. (2013: 507) posit that there exists significant disagreement amongst researchers on whether criteria based on laboratory experiments apply to buildings with natural ventilation. It is questionable whether these standards can universally apply to every category of buildings, seasons and inhabitants by disregarding the significance of contextual influences that can challenge individuals' reactions to a specified thermal condition. This argument proves that HAM is suitable for heat evaluation in kitchen environment due to higher comfort temperatures among workers.

In the context of kitchen design, the mention of a good building design, conditioning of space with heating, cooling and ventilation achieves thermal comfort (Alfano *et al.* 2014: 326). Kim *et al*. (2019: 1) conclude that different parts of a building can have widely varying warm spots, and even in the same settings, individuals favour different temperatures. Olesan *et al*. (2020: 33) analysed IEQ for air-conditioned buildings where the range of thermal preferences were estimated from the HBM and in natural ventilation buildings, the HAM was used to define the boundaries of the comfort zone.

2.4 Heat indices in occupational settings

There are increasingly severe limitations on human activity in tropical and mid-latitudes during peak months of heat stress with continued global warming (Dunne *et al*. 2013: 1). To calculate the anticipated repercussions from human action, manufacturing and security forces specify a standard for regulating work during a typical 8-hour shift to reduce the risk of overheating and its effects.

The International standards that set the parameters for the evaluation of thermal comfort enjoy universal consensus. These are specified in:

Standard ISO 7730 (BSI 2005) for the HBM

ASHRAE/ANSI Standard 55 (ASHRAE 2010) and,

CEN Standard 15251 (BSI 2007).

The two latter standards include versions of the HAM (Rupp *et al*. 2015: 179). The amended ANSI/ASHRAE-55 (2010) standard appears to be better suited to the kitchen. The standard specifies the combinations of six indoor thermal environmental factors and personal factors that will be acceptable to a majority of the occupants within the built space and can vary in time (Lin and Deng 2008: 70).

The aforementioned standards fail to address non-thermal environmental factors such as IAQ, acoustics and illumination that affect comfort in commercial kitchens. The current study attempts to investigate some of the above-mentioned factors that could affect thermal comfort in Durban kitchens as given in section 1.4.

ISO 7730 presents a thermal sensation scale to quantify people's thermal sensation within a built environment (Parson 2009: 6). However, Simone *et al*. (2013: 1014) disagree with the suitability of the scale as kitchens can be very hot. Although the seven-point thermal sensation scale has been used extensively, its appropriateness is restricted by establishing a one-dimensional relationship between physical parameters of indoor environments and subjective thermal sensation (Schweiker *et al*. 2017: 572). The scale that ranges from hot to cold allocates indices from +3 to –3. The index assumes that people voting +2, +3, –2, or –3 on the thermal sensation scale are dissatisfied (Zuhaib *et al*. 2018: 18). ISO 7730 has been criticised because of its lack of theoretical validity (Parsons 2001: 23), and does not adequately describe comfortable conditions (Nicol 2004: 628). The PMV/PPD index was developed for temperate western conditions. The Standard does note that deviations may occur due to ethnic and geographic dissimilarities, sick or disabled people and excludes children. The standard applies to indoor environments where steady-state thermal comfort or moderate deviations from comfort occur. This allows for interpretation and judgement

(Parsons 2001: 24). EN ISO 7730 accepts the criteria for the PMV model guidelines in the thermal sensation scale (Olesen 2007: 741). This Standard was last reviewed and confirmed in 2015 and remains current as per Technical Committee: ISO/TC 159/SC 5 of ergonomics of the physical environment.

The guidance on working temperatures in commercial kitchens from regulation appears to be elusive. The Health and Safety Executive (HSE 2013: 1) holds responsibility for regulation and contributes information about the risks of overheating when working in hot conditions, it does not address minimum compliance requirement and issues of thermal comfort in the workplace. In heat stress environments such as bakeries and catering kitchens, thermal comfort remains an issue all year round, more particularly, during summer when there is a greater threat of heat stress for labour (HSE 2013: 1). A meaningful maximum figure cannot be given due to the high temperatures such as those at bakeries.

HSE states that the temperature in workrooms should be at least 16 °C or 13 °C if much of the work involves rigorous physical effort. It seems that these standards are applicable to temperate climates and not suitable for countries with tropical or semi-tropical climates. Ethnicity and climate conditions are predictors of an individual’s thermal adaptation and comfort (Schweiker 2018: 311). Despite EN15251 permitting workplace operative temperature in winter to range from 18 °C to 23 °C and 22 °C to 27 °C in summer (Olesen 2015: 18), the South African Weather Services (2020: 1) reports a wide temperature range in Durban with midwinter from 16 °C to 23 °C (60 °F to 74 °F) and midsummer temperatures from 28 °C to 33 °C (82 °F to 91°F).

A Heat Stress Index (HSI) according to Parsons (2011: 1) incorporates the effects of the environmental parameters in any thermal environment in a manner that variations in thermal conditions will affect its value. The HSI indicates heat exposure and boundaries for safe temperatures. Determination of this index will contribute to kitchen design, fostering the intent in Objective 2 of this study. HSI are categorised as rational, empirical or direct **(**Epstein and Moran 2006: 391). Rational indices emerge from data concerning the heat balance equation; empirical indices are based on physiological responses from the human responses such as sweating; direct indices are established with the dimensions of environmental parameters such as WBGT, RH and airflow (Roghanchi and Kocsis 2018: 10).

2.4.1 The Wet Bulb Globe Temperature

The Wet Bulb Globe Temperature (WBGT) indicates occupational health of kitchen workers and helps to understand the nature of Objective 2 and Objective 3 of this study that seeks to devise indoor environmental standards for the design of restaurant kitchens concerning heat stress among food production workers. The WBGT (ISO 7243: 1989a) is widely prevalent in determining the direct HSI that incorporates heat, humidity, airflow and heat radiation (Havenith and Fiala 2016: 262). Research work in kitchen environments has long used this measure (Rabeiy 2018 and Sajedifar *et al.* 2017). WBGT is by far the most widely used HSI throughout the world for describing environmental heat stress (Epstein and Moran 2006: 391).

Based on the WBGT index, the American Conference of Governmental Industrial Hygienists (ACGIH) as per Spellman (2006) published the permissible heat exposure Threshold Limit Value (TLV) that refers to temperatures settings at which all employees can be frequently subjected to without any ill-health. This criterion was also adopted by the Occupational Safety and Health Act (OSHA); National Institute for Occupational Safety and Health (NIOSH); American Industrial Hygiene Association (AIHA), American College of Sports Medicine (ACSM) and the US Army (Taylor 2006: 333).

WBGT gained popularity owing to its simplicity and convenience of use. According to Alfano *et al*. (2014: 955), the WBGT has been condemned for becoming obsolete after 60 years of use, as it has restricted use in high humidity low air movement conditions. However, WBGT can be measured in extreme heat. WBGT overestimates the stress when used outdoors in situations where the largest source of radiant heat is the sun (Holmer 2010: 5). The coefficients in this index- air temperature, black globe temperature and natural wet bulb temperature are calculated empirically, and the index is used universally as a safety index for workers in various occupations (Epstein and Moran 2006: 391).

WBGT is used widely for evaluation of heat in commercial kitchens by Haruyama *et al.* (2010: 141), Li *et al.* (2012:141), Matsuzuki *et al.* (2013: 173), Simone *et al*. (2013: 1008) Subramaniam and Murugesan (2015: 525), Hima Bindu and Reddy (2016: 1320), Singh *et al*. (2016: 7) and Alam *et al*. (2019: 2). As per the Canadian Centre for Occupational Health and Safety (CCOHS) and NIOSH, this technique reveals physiological reactions to temperature by the human body (Jacklitsch *et al.* 2016: 59). The international standard limit of the WBGT is around 27 °C, the specification is conditional on the basic metabolic rate (BMR), acclimatisation state and clothing (ASHRAE 2010: 20). Preventative actions should be taken when the WBGT climbs above 27 °C. Pursuant to Objective 2, the current study will also measure the WBGT of the kitchen worker to ascertain their heat stress.

2.4.2 Discomfort index in South Africa

The discomfort index (DI) is an important indicator that measures the human heat sensation for different climate conditions (Xu *et al.* 2017: 598). According to the Department of Environmental

Affairs (RSA), the effect of heat stress on a worker is evaluated considering the combined effect of temperature and humidity (South African Weather Services 2020: 1). The formula to calculate the discomfort index is:

(2 x T) + (RH/100 x T) + 24

where T = dry-bulb or air temperature in °Celsius and RH = percentage relative humidity. This index gives guidance on the degrees of discomfort:

90-100 - very uncomfortable
100-110 - extremely uncomfortable
110 and more - hazardous to health

These measures will form the basis of the interpretation of discomfort experienced in Durban kitchens (section 1.4). Occupational health of kitchen workers will help to understand the thermal environment in kitchens and evaluate heat stress among food production workers using gas and kitchen appliances to formulate environment design standards. Epstein and Moran (2006: 393) mention DI which besides WBGT is the only index in daily use for more than four decades. However, Zululand Fire Protection Association (2020: 1) uses an international formula adopted from Giles *et al.* (1990: 100) namely, discomfort index.
Discomfort index DI = T-0.55 x (1-0.01 H) x (T-14.5)

T: air temperature (°C),
H: relative humidity (%)

Other indices such as Heat Index, Humidex and Universal Thermal Climate Index (UTCI) are indices valid for outdoors only. Table 2.1 (page 22) indicates the SA limit for heat stress for mining workers.

2.4.3 Heat index or apparent temperature

Havenith and Fiala (2016: 288) proposed the concept of apparent temperature (AT) which is a measure of discomfort from combined heat and humidity. A simplified hot weather version of the AT, known as the heat index, is used by the National Weather Service (NWS) in the United States. Conversely, the NWS (2020: 2) emphasises that heat indices are only valid for shady areas.

2.4.4 Humidex

Heat Index (HI) and Humidex (HX) are direct indices, empirically derived from air temperature and humidity to convey a ‘feels like’ temperature to the public (Havenith and Fiala 2016: 289).

Humidex is used in Canada for general public heat stress assessments. The relationship between humidex and comfort is subjective and technically, it cannot be directly compared to WBGT. This flawed and imperfect index from a scientific point of view does not take into account factors, such as strong winds and whether the person is walking in the sunshine, which significantly increases how hot the person feels (CBC News 2013: 1). Humidex very often leads to the underestimation of the workplace dangerousness and poor reliability of comfort prediction when it is used in indoor situations (Alfano *et al.* 2011: 95).

Table 2.1 References for SA 'limits' for heat stress (Webber 2003: 314)

Category	Temperature range	Interpretation	General action
A: Abnormally hot	WB ≥ 32.5 °C or DB ≥ 37.0 °C	Unacceptable risk of heat disorders	Work may be undertaken only on the basis of or Globe temperature ≥ 37.0 °C expert risk assessment, supervision and protocols
B	29.0 °C ≥ WB ≤ 32.5 °C and DB ≥ 37.0 °C	Potentially conducive to heat disorders	HSM mandatory Globe temperature: as for DB
C	27.5 °C ≥ WB ≤29.0 °C and DB ≤ 37.0 °C	Potentially conducive to heat disorders	HSM mandatory Globe temperature: as for DB
D	WB ≤ 27.5 °C and DB ≤ 32.5 °C	Risk of heat disorders negligible	No special precautions. Environmental monitoring Globe temperature: as for DB must be sufficiently sensitive to detect critical upward drifts in the environmental heat load. The monitoring program to satisfy this requirement should be specified.

Key: WB - Wet bulb, DB - dry bulb

2.5 Heat stress legislation

Heat stress legislation deliberates the dangers of hyperthermia when employed in hot workplaces and provides regulation on how to avoid it (HSE 2013: 1). In South Africa, Environmental Regulations for Workplaces, 1987 by SA Department of Labour regulates working conditions in heat where the time-weighted average WBGT index, calculated for an hour should not exceeds 30 °C in the environment in which an employee works. It specifies that the employer requires to take steps to reduce the index below 30 °C, and where hard manual labour is performed, the worker should be certified fit to work in such an environment by a medical practitioner. Moreover, an employee needs to consume at least 600 ml of water every hour to acclimatise to working in such a working environment. This implies that commercial kitchens with temperatures above 30 °C need to make provision for workers to frequently drink water.

In the UK, the Health and Safety at Work Act 1974 regulation on indoor workplace temperature, states that during working hours, the temperature in all workplace inside buildings should be reasonable (HSE 2013). The major factors to consider that may affect an individual's tolerance are: work rate, working climate, heat source, employee clothing and respiratory protective equipment; employee’s age, build and medical factors (Health and Safety International 2018: 1).

Occupational Health and Safety (OSHA) asserts that age, body weight, physical fitness, degree of acclimatisation, BMR, use of alcohol or drugs and medical conditions affect a person's sensitivity to heat (OSHA 1970: 1) including type of clothing worn. A heat-related illness (HRI) occurs when there is an increase in the worker's core body temperature above a healthy temperature. Since individual susceptibility varies, it is difficult to predict how the heat will affect workers. The act claims that although heat hazards are common in indoor and outdoor work environments, HRI and fatalities are preventable.

The OSHA declares that temperatures of dry bulb less than 33 °C are low risk whereas in SA it is 32.5 °C outdoors (Webber *et al*. 2003: 314). The maximum limit for work to continue in the USA is 38 °C, 46 °C in salt mining in Germany and in SA it is 37 °C as the humidity levels are much higher.

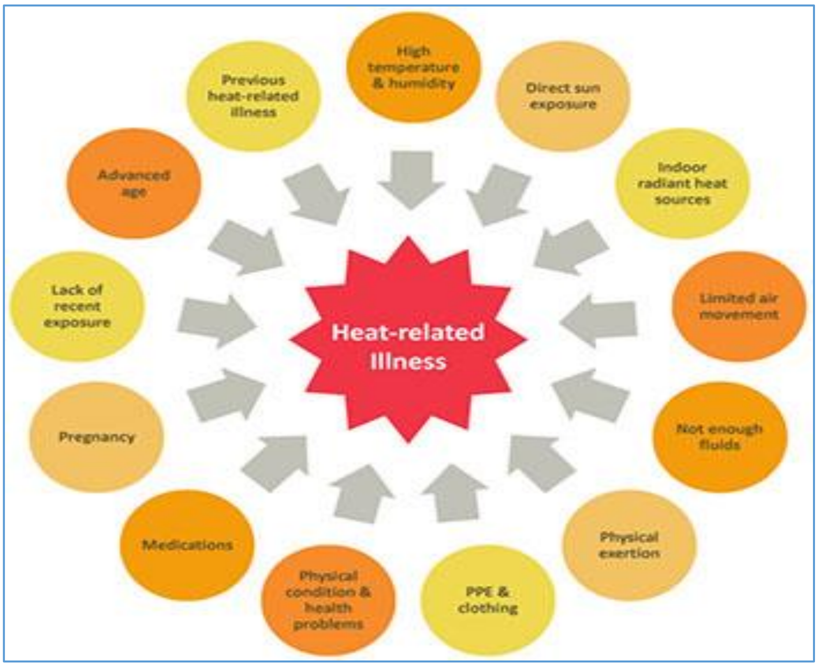


Figure 2.1 Heat-related illness risk factors (NIOSH 2015: 35)

2.6 Heat stress precaution

Heat stress is a significant risk for employees, especially kitchen workers in the hospitality sector. Extreme contact with heat conditions can cause HRI (European Agency for Safety and Health at Work 2008a: 2) adding that prickly heat (rash) and dizziness are the early indications of heat strain. If heat stress is not recognised, and treatment not provided, it can have severe effects on the body, such as heatstroke, exhaustion and cramps, heat syncope and death. Heat can also increase workers’ risk of injuries, resulting from perspiration, clouded safety goggles, dizziness and may reduce brain function responsible for reasoning ability, creating additional hazards (NIOSH 2015: v). Hansen *et al*. (2018: 5) report that the minor symptoms include a worker looking pale, feeling tired and distressed; experiencing headaches, muscle fatigue, and exhaustion and fainting. Serious cases include individuals being dehydrated, vomiting, losing consciousness or experiencing chest pain. Deaths of workers have been reported even after seeking medical care (Totsky 2006: 2).

2.7 Heat adaptation

Work-related heat exposure endangers the well-being of a worker (Xiang *et al*. 2014a: 91), resulting in impaired work performance and work capacity as well as HRI (Gubernot *et al*. 2014: 1785). Occupational environments that include hot and humid climate create a strenuous and potentially dangerous thermal load for a worker. The author adds that heat prevention strategies and international thermal ergonomic standards to protect the worker were developed largely for temperate western settings, and their validity and relevance are questionable for some geographical, cultural and socio-economic contexts where the risk of excessive heat exposure can be high.

According to Taylor and Cotter (2006: 34), an individual is an active agent interacting with and adjusting to the worker-environment system. However, several studies have raised concerns that HRI is a common occurrence and may be unreported in the industry (Hansen 2018: 1). It is, therefore, necessary to review the heat adaptations and prevalent practices followed in different occupational settings to comprehend the magnitude and severity of the threats to the workers and industry. The ergonomic and food production literature has established that constant exposure to extreme heat hampers worker productivity (Kosonen and Tan 2004; Livchak *et al.* 2005; Kosonen 2006; Yuan *et al*. 2013; Matsuzuki *et al*. 2013; Hossain and Majumder 2017).

Humans are priviledged to have an immense capacity to adjust physically, physiologically and psychologically to a broad range of environmental conditions (Nikolopoulou and Lykoudis 2006: 1464). Human response to heat is influenced by a range of interactions such as worker demographics, context, environmental interactions and cognition that influence human responses to heat. Schweiker (2020: 34) presents a framework for human-building resilience of occupants due to distinctive aspects like toughness, ability to cope, or capacity to recover, all related to adaptation.

2.8 Workplace heat exposure

The potential impacts of workplace thermal experience are misjudged due to the underreporting of heat disorders (Xiang *et al.* 2014a: 94). Global warming and climate change will unquestionably increase the impact of heat on individuals who work in hot workplaces located in hot climate areas (Gao *et al*. 2018: 359); (Lundgren-Kownacki *et al.* 2019: 1). Workers labouring in tropical locations with hot and humid climate are exposed to thermally stressful conditions that can create HRI (Krishnamurthy *et al*. 2017: 99). Workers commonly at risk include growers, building workers, firefighters, mineworkers, militaries, as well as cooks and bakers, who are exposed to extreme heat in the kitchens (Xiang *et al.* 2014a: 91). Kjellstrom *et al*. (2014: 1) predicts that the temperature may rise by 2 °C to 4 °C during the hot periods, and this alters the occupational heat from 'low risk' to 'moderate or high risk' in most of SA.

2.9 Thermal homeostasis and human system

Humans have the ability for acclimatizing to high temperatures due to the ability to perspire (Taylor 2006: 97) and the various thermo-regulatory mechanisms in the human body that maintains heat balance. According to Parsons (2009: 5), high heat exposure or heavy work causes heat strain as the core body temperature rises above 37 ºC that can cause malfunction of body system and progress into death. Sweating without liquid replacement leads to dehydration during heat stress. Kitchen workers can be dehydrated due to inadequate water replacement. Factors that influence an individual worker's ability to work in hot environments are individual characteristics, thermal environment and task requirements.

Pacing to reduce physical activity or frequent breaks reduces the body's internal heat production (Lundgren *et al.* 2013: 10), called autonomous adaptation to climate change (Kjellstrom *et al*. 2013: 56). According to Noakes (2011: 30), muscles develop fatigue with use, and the function of the central nervous system is to maintain physiological equilibirium. Reduced work capacity in a hot, humid, noisy kitchen increases stress and negatively affects performance (British Columbia Campus 2020: 1).

Additionally, longer shift with strenuous work, without reasonable breaks could lead to lower productivity (Parsons 2009: 5). However, Zou and Li (2020: 82) strongly recommended that workers take a break at least every two hours in severely hot environments. In fact, Parson *et al*. (2011: 27) have shown that for every degree Celsius rise in temperature above 18 ºC means an extra 0.36 % of hospital admissions. A WBGT range of 25 ºC to 40 ºC occurs at ambient temperatures in the range 30 ºC to 45 ºC are typical during the summer in tropical and sub-tropical climates. At WBGT above 40 ºC, it is challenging to perform any physical work (Parsons 2011: 62).

2.10 Climatic heat factors and human adaptations

In many tropical and sub-tropical zones, climate change and global warming are aggravating conditions (Lundgren and Holmer 2013: 20) with high temperatures and high humidity typical in these locations. The climate in the city of Durban is Humid Sub Tropical Coastal (Conradie 2012: 3). Such hot-humid conditions observed by Lucas *et al.* (2014: 2) create a thermal extreme as heat loss from the body to the environment becomes challenging, and internal body temperature rises uncontrollably. Zhang and de Dear (2019: 10) report that the local climate considerably affects heat sensation. Occupants from warmer regions are inclined to sense cold considerably than their peers from cooler regions that suggests a long-term acclimatisation. Interestingly, this climatic adaptation is consistently distinct in women than in men and mentioned in formative work of Hanna and Brown (1983: 276).

The effect of climate on local landscapes also has a profound effect on working temperatures. Durban's sub-tropical climate makes it hot and humid, so naturally, plants and grass grow faster (Life Green Group 2020: 1.). The vegetative cover assisting in increasing human radiative heat loss (Hanna and Brown 1983: 268). However, an undesirable combination of high humidity and high ambient temperatures characteristic of tropics exhibit an Urban Heat Island effect (UHI). The UHI effect contributes to additional heat exposure, thus affecting housing and indoor environments in a complex way (Lundgren-Kownacki *et al.* 2019: 1). Yamaguchi and Ihara (2020: 15) predict that in tropical and subtropical regions, heat will intensify due to the UHI effect accelerating autonomic heat loss mechanisms amongst workers (Schulte and Chun 2009: 548). Xiang *et al.* (2014b: 90) posit that elevated workplace heat levels pose a growing challenge to workers health and safety.

Van Hoof *et al*. (2017: 128) conclude that there are regional differences in the thermal sensation and potential for regulating the thermal condition. Climate, building traditions, clothing habits, family patterns, welfare, and numerous other factors differ so much between countries and continents that there are obvious differences between people and options for thermal control. Barthelmes *et al*. (2020: 309) urge that occupants regulate their indoor environment according to their comfort standards and a series of appropriate psychological or social factors. Rijal *et al*. (2020: 771) demonstrate the scope of human adaptation to deliver satisfactory surroundings for office workers are by way of selecting appropriate clothing, by keeping windows open or close, and by switching on cooling when desired. Lin *et al*. **(**2011: 302**)** add that heat exposure, comfort expectation, apparent thermal control and interval of heat endurance are among psychological and behavioural factors that contribute to the heat balance of the human body.

The sub-sectors that following will show that as a social-cultural phenomenon, thermal comfort relies on the intersection of climatic conditions, cultural expectation and everyday activities (Bulkeley and Fuller 2012: 64).

2.10.1 Physiological adaptation

Hellwig *et al*. (2020: 532) argue that factors influencing the physiological regulations for heat governs a human body's heat balance and form the basis for steady-state thermal perception models. They are accomplished by behavioural and psychological adaptation and acclimatisation processes. Table 2.2 conveys the researcher's view of prior studies of physiological adaptation in three classes: firstly, individual factors that constitute 30 %, and secondly, genotype comprising 8 % and acclimatisation making up the remaining 62 %. This is consistent with Objective 2 to explore individual factors, selected genotypes and acclimatisation that play a role in thermal adaptation among kitchen workers.

2.10.1.1 Individual factors

The representation of individual factors that determine physiological adaptation is stated by Farnell *et al*. (2008: 238) as comprising fitness level, body composition, age, gender and race that influence an individual's ability to thermos-regulate. Ravindra (2015: 56) adds on the influence of perceived thermal comfort:

- Food (which included both breakfast and lunch)
- Caffeine (Hot and cold)

The studies in column I of Table 2.2 explain that heat tolerance is impaired with age and recognised as a risk to physiological adaptation.

Younger people acclimatised better than their older counterparts did. Behavioural adaptation during extreme heat is essential for elderly whose heat regulation capacity may be compromised due to age or illness (Hansen *et al*. 2011: 4724). Van Hoof *et al*. (2017: 123) argue that the current models for assessing thermal comfort are not sufficiently accurate to be used for older adults as many factors related to thermoregulation are impaired in older adults. In the studies represented in Table 2.2 (page 28), variations in body fat (column IV) and sweat rate are key triggers for differences in physiological adaptation between genders (column II).

The better tolerance of women in humid heat is a physiological adaptation that is likely to be attributed to the lower sweat rate of women (Xiang *et al*. 2014a: 98). Skin temperatures at rest are lower among females than men despite the increased fat content of females (Lundgren *et al*. 2013: 8), but the body temperatures are higher than males during physical work (Haruyama *et al.* 2010: 139). Interestingly, women perceive the same thermal environment significantly cooler than men in all circumstances (Parsons 2002: 593). Alshaikh and Alhefnawi (2020: 391) find that females are less sensitive to hot temperature than males; sensitivity to humidity and airflow does not differ between genders (Zhang and de Dear 2019: 10). This is supported by Kumar *et al.* (2020: 1) who find that women had about 1.5 °C higher comfort temperature compared to men.

Table 2.2 Studies of physiological factors affecting heat tolerance

FACTORS	I	II	III	IV
	Age	**Gender**	**Fitness**	**Body Fat and Physical Activity**
AUTHORS	Deschenes (2014) Hansen *et al.* (2013) Lundgren *et al.* (2013) Banwell *et al.* (2012) Kalkowsky *et al.* (2006) Taylor *et al.* (1995) Farnell *et al*. (2008) Van Hoof *et al*. (2017)	Mathee *et al.* (2010) Lundgren *et al.* (2013) Xiang *et al.* (2014) Haruyama *et al.* (2010) Farnell *et al*. (2008)	Hansen *et al*. (2013) Carter *et al*. (2003) Hanna and Brown (1983) Farnell *et al*. (2008)	Parameswarappa and Narayana (2014) Bedno *et al*. (2014) Hanna and Brown (1983) Farnell *et al*. (2008)

The studies in column III of Table 2.2 confirm that frail health leads to diminished physiological adaptation. Whilst a linear body, according to Hanna and Brown (1983: 277), promotes heat loss, those with poor health remain at risk due to heat (Hansen *et al.* 2013: 2). Soebarto *et al.* (2020: 155) claim that research has established the relationships between temperature, health and well-being, mortality and morbidity.

The study of Bedno *et al.* (2014: 466) represented in column IV of Table 2.2 cautions that the risk of heat illness increases with excess body fat. This is despite a higher body surface area (Parameswarappa and Narayana 2014: 861). Hence, Hanna and Brown (1983: 278) assert that obese workers sweat more profusely and have lower cardiovascular fitness. In addition, adipose tissue has less water content, absorbs less heat, and therefore, reduces heat tolerance.

2.10.2 Genotype

Genetic adaptation is the modification in part of an individual or a group of people with continuous progression beyond generations (Brager and de Dear 1998: 86). Variations in thermal tolerance are intensified by ethnicity and cultural differences. A significant feature in the context of human heat adaptation relates to individual genotype. Earlier, Taylor (2006) reviwed ethnic differences in thermoregulation: genotypic versus phenotypic heat adaptation wherein the following are discussed. The second factor in the context of human heat adaptation relates to individual genotypes commonly reported to lie in sweat glands (44 %), BMR (27 %), body surface (2.8 %), blood flow (8.4 %), skin colour (7 %) and nasal index (14 %). However, all these factors will not be elaborated as these features were not a part of the current study. Table 2.3 (page 30) represents a few genotypic factors, and the review of literature focuses on skin colour, type of nose and type of hair as relevant to this study.

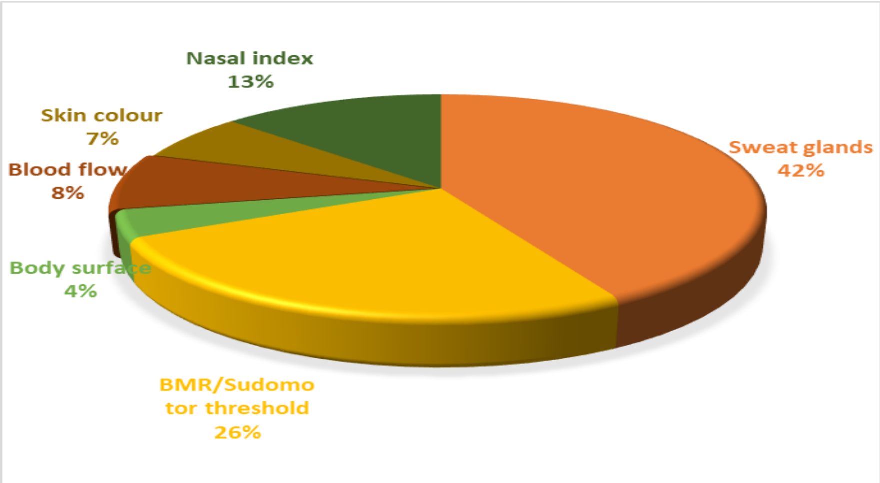


Figure 2.2 Ethnic adaptation to heat

2.10.2.1 Skin colour

Less frequent in the literature are investigations of the role of skin colour and thermal adaptation. Whilst white and dark skins are similar in terms of thermal exchange, dark skin is found to safely absorb 30 % to 40 % more sunlight than white skin (Hanna and Brown 1983: 278). In prior studies, Roberts (1977: 329) asserts that dark skin is less susceptible to sunburn damage as is the case among Negroes, as darker skin pigmentation triggers earlier activation of body heat loss mechanisms.

White skin has greater potential to have severe sunburn damage to skin disturbing the functioning of sweat glands and thus heat regulation. Pigmentation is correlated with the amount of UV radiation a region receives which is highest at lower latitudes (Aryan Anthropology 2015: 1).

UV radiation was probably a powerful agent selecting for high levels of melanin production in early humans (Jablonski and Chaplin 2010: 8962). Typically, the darker skin pigmentation is inclined to be more hot-climate acclimatised as warm tropical regions receive the highest amounts of UV radiation. According to Powell (2017: 3), it may seem that black people do not blush simply because the darker skin colour hides it. Flushing is an indicator of heat discomfort and probable heat stress (Gao *et al.* 2018: 359) or being too hot (Villines 2018: 1). It therefore seems that heat discomfort of dark skinned people maybe ignored as they do not show visible heat stress symptoms in hot kitchens.

2.10.2.2 Hair type

According to Handzlik (2018: 1), skin colour adaptation is not enough for survival in hostile environments. In order to better adapt to an environment, natural selection will favour people with different skin colour, skin type, hair type and numerous characteristics. Humans who lived in tropical places evolved to have wider noses to absorb more oxygen, while the ones who lived in the colder Northern parts evolved to have narrower noses for protection against the cold wind (Panko 2017: 2).

Marshall (2014: 1) claims that populations are naturally suited to their environments and climate and adapt to that region of the planet to increase survival. Eaaswarkhanth *et al.* (2014: 260) noticed that changes in specific genes responsible for keratin structure played a significant role in the final shape of an individual's hair. With temperature as a factor, curly hair has a protein trichohyalin that has a primary influence over hair curl. Those with curly and coiled hair, as well as darker skin and wider noses, are scientifically linked to the continent of Africa, where the climate is hot.

Curlier and drier hair are beneficial in hot climates. The hair contributes to protection against direct sunlight, absorbs water and sweat and provides a cooling effect. Straight and oily hair in hot climates would be vulnerable to scalp burn and overheating (Marshall 2014: 1). Also, Thwaites (2017: 1) expresses that afro hair evolved as a defence against sunlight to protect the scalp from harmful UV light.

Table 2.3 Ethnic adaptation to heat

FACTORS	I **Skin**	II **Nasal Index**	III **Hair**
AUTHORS	Thompson (1954) Roberts (1977) Jablonski and Chaplin (2010) Meyer (2012) Tang *et al*. (2015) Zaidi *et al.* (2018)	Crognier (1981) Collins (1999) Church (2010) Noback *et al.* (2011) Meyer (2012) Holton *et al.* (2013) Patki and Ito (2016) Szalay (2017) Zaidi *et al*. (2018)	Marshall (2014) Thwaites (2017) Eaaswarkhanth *et al.* (2014)

2.10.2.3 Nasal index and type of nose

A further genotype affecting heat dissipation is the individual nasal index. Variations in the nasal index have been reported to represent an adaptation to climatic conditions (Patki and Ito 2016: 66); (Church 2010: 38); the nasal index has a direct relationship to the temperature and humidity of an area. In hot, humid conditions, a low, broad nose better serves to dissipate heat. Humans who lived in tropical places evolved to have wider noses to absorb more oxygen, while the ones who lived in the colder northern parts evolved to have narrower noses for protection against the cold wind (Panko 2017: 2).

Zaidi *et al.* (2018: 1) claims that the nose shape may be a local adaptations to climate as the width of the nostrils is strongly correlated with temperature and humidity. Wider noses are more common in warm and humid climates, while narrower noses are usually found in cold and dry environments. Similarly, Noback *et al*. (2011: 599) suggests that the wide nose helped humidify and warm cold air (Szalay 2017: 1). For example, the Alaskan Inuit and Siberian Buryat populations are associated with a longer, narrower nasal cavity and in sub-Saharan African populations with the wider nasal cavity.

2.10.3 Acclimatisation

Seasonal and climatic adaptations are both an acclimatisation process and a sub-category within phenotypic adaptation (Schweiker *et al.* 2018: 308). Acclimatisation refers to the adaptive changes within an organism occurring in response to its natural climate and can occur in both the short term and long term (Zhang and de Dear 2019: 2). Hanna and Tait (2015: 8035) claim that thermoregulation and acclimatisation determine human heat tolerance and vulnerability to heat stress, whereas, Hanna and Brown (1983: 274) indicate that acclimatisation is the most important factor known to influence individual response to heat. Young (1996: 1) adds that Australian Aborigines have an acquired thermal adaptation in response to their unique lifestyle and environment. Lundgren-Kownacki *et al.* (2019: 10) suggest accordingly adopting a systematic heat exposure regime to induce workplace acclimatisation. Malgoyre *et al.* (2020: 1) report that naturally heat acclimatization soldiers had a higher level of heat tolerance during exercise in the heat, even 6 months after returning from the previous desert mission, than that of their non-acclimatized counterparts.

2.10.4 Psychological adaptation

Except for Nikolopoulou and Lykoudis (2006: 1466), there is no original empirical study to suggest that individual psychological makeup affects heat adaptation. However, earlier study by Brager and de Dear (1998: 85) offers similar views on acceptability, an emotional, altered perception and reaction to sensory information due to experience and expectations. Given the huge variations for adaptation and ethnic groups in commercial kitchens in Durban, the personal opinion of workers on comfort in the work environment will help to address study Objective 3.

Nikolopoulou and Lykoudis (2006: 1466) offer three distinctive psychological adaptive processes: firstly, habituation that includes naturalness, experience, period of exposure, secondly, environmental stimulation; thirdly, expectation and perceived control. Critical parameters for satisfaction with thermal environments include individual choice, recollection and expectations. The authors add that in effect, the extent to which acclimatization and expectation alter one's perception and reaction to sensory information is physiologically modified for outdoors and indoors (Nikolopoulou 2011: 10). All parameters according to Nikolopoulou and Steemers (2003: 96) are interrelated and ambiguous and being influenced by each other; the physical environment and psychological adaptation are complementary.

For example, Kumar *et al*. (2020: 16) found that students having limited access to options like the closing of windows, doors, and regulation of fan speed to improve their thermal conditions are psychologically adapted to the conditions prevailing inside the natural ventilation workshop. Day *et al*. (2020: 474) report greater thermal satisfaction in hot and humid climate buildings that may be attributed to the control factor. It allowed occupants to control lights and fans, operate windows and ventilation louvres.

2.10.5 Behavioural adaptation

As per Hellwig *et al*. (2020: 533), another response to thermoregulation is behavioural; comfort/distress awareness initiates behavioural adaptation. The cultural practices of siesta, pacing, and wearing sombrero have provided practical ways to adapt to the hot environment (Hyatt *et al.* 2010: 2). Humans, according to Boyd *et al*. (2011: 10918), have built habitat-specific cultural heat adaptations. Culture and genetics are increasingly being thought of as intimately connected, each influencing the natural progression of the other leading to a 'gene-culture co-evolution' (Goldman 2014: 2). The author further suggests that traditions and cultural practices can influence the path of human evolution.

Table 2.4 (page 33) identifies the behavioural factors that affect heat in this literature study as follows: cultural factors at 50 %, economic factors at 30 %, social factors at 10 % and those with health variables at 10 %. Behavioural modification among people of lower socioeconomic status is limited as they are more likely to live in sub-standard housing that lacks adequate ventilation and air-conditioning (Hansen *et al*. 2013: 1), and as these workers cannot cool their bodies adequately at night, such workers face additional risk (Frimpong 2015: iii). Schweiker *et al*. (2017: 579) are convinced that behavioural adaptation plays an important role in workspaces with and without mechanical cooling.

Van Hoof *et al.* (2017: 126) find that to achieve thermal comfort, the elderly in the UK first adjust their behavioural actions and then adjust their thermal environment. They may reduce their clothing layer, have a rest or open windows. Older adults in Australia showed adaptive behaviour during hot conditions such as reducing physical activities, staying indoors, wearing cool light clothing, drinking more fluids and using an air-conditioner if possible. New *et al*. (2020: 786) propose that to promote adaptability to thermal comfort, workers can be encouraged to wear comfortable clothes with natural fibres.

Table 2.4 Empirical work on behavioural factors affecting heat tolerance

FACTORS	I	II	III	IV
	Social	**Cultural**	**Economic**	**Health**
AUTHORS	Budd (2008) Hansen *et al*. (2013) Gubernot *et al*. (2014)	McCollough (1973) Pool (1987) Lambert (1992) Brake and Bates (2002) Hyatt *et al.* (2010) Boyd *et al*. (2011) Chavez (2011) Lundgren *et al*. (2013) Kenawy and Elkadi (2013) Goldman (2014)	Hansen *et al*. (2013) Lundgren *et al.* (2013) Gubernot *et al.* (2014) Lucas *et al.* (2014) Frimpong (2015) Kjellstrom *et al.* (2013) Van Hoof *et al.* (2017)	Tawatsupa *et al*. (2010) Banwell *et al.* (2012) Montero *et al.* (2013)

However, several studies indicate that workers refrain from behavioural modifications. Lucas *et al.* (2014: 5) add that income and livelihood factors can force workers to ignore psycho-physiological indicators of heat strain and work extended hours while enduring longer periods of high temperatures in poor working conditions. Grunlond (2013: 8) review racial and socioeconomic characteristics that are associated with increased susceptibility to heat-associated health effects. Similarly, the social and economic conditions that affect people is also positively associated with their health (Hansen *et al*. 2013: 1) where persons with poor health are at risk due to heat (Banwell *et al.* 2012: 1) and not capable to make behavioural adaptations. A preliminary study in Thailand revealed that ill-health is widespread, particularly when workers exposed to excessive heat cannot cool down. They can experience severe psychological distress caused by heat exhaustion (Tawatsupa *et al.* 2010: 9) due to limitations on behavioural changes.

Likewise, clothing is a critical factor in thermal comfort according to Fanger's (1970: 244) comfort equation. Behavioural adaptation varies with season and needs to be considered to assess perceived thermal satisfaction (Park *et al.* 2018: 6). Clothing insulation differences between the genders affect thermal dissatisfaction among men and women. Similarly, Schweiker *et al*. (2017: 579) suggest that Thermal Scales should be validated by correlating them with aspects of thermal sensation assessed by behavioural assessments. The behavioural and physiological responses elicited for models used in thermal comfort research are in need of improvement.

Along with personal control, technological adaptation has come to fore. André *et al*. (2020: 990) claim that reports on thermal comfort show that roving comforter (personal comfort device app) videos escalates users' thermal comfort. These are dominated by modification of the surroundings that commonly include opening windows/shades, turning on fans or operating HVAC controls. Rissetto *et al*. (2020: 266) add that attitudes and values towards technology such as a ceiling fan may impact on behavioural adaptation.

2.11 Kitchen worker risks

Studies of sectors involved in heat adaptation to occupational settings in Appendix 1 represent assorted sectorial interests, including agriculture, mining, forestry, firefighting, road traffic management, military and construction. Loss of well-being and productivity are commonly associated with heat exposure in these sectors. Decisions to adapt or not are taken at different echelons, ranging from individuals to national planning agencies (Knowlton *et al*. 2014: 3474). The restaurant industry constitutes high-risk occupational classes of workers, and it embraces chefs, cooks, bakers and other kitchen workers.

Work in commercial kitchens is accomplished in hot environments (Matsuzuki *et al.* 2011: 171). In fact, temperatures in commercial kitchens in China can go as high as 54.0 °C, with inadequate ventilation and without a cooling air supply system (Li *et al.* 2012: 139). Simone *et al.* (2013: 1014) find that the indoor climate in commercial kitchens is often unsatisfactory and climate zone can influence thermal conditions in the kitchens.

The International Labour Organisation (ILO 2001) report that in the hot kitchens, where worker density was high and cooking procedures generate heat, temperatures were slightly raised compared to other areas of activities. Kitchen staff are at most risk where temperatures can be elevated by machinery, cooking equipment and poor ventilation. Dry temperatures in the kitchen can sometimes even exceed 30 °C (ILO 1998: 72).

Increased heat in kitchens from fuels and cooking methods increase workers' risk. For example, Zhao and Zhao (2018: 980) add that Chinese cooking practices generate a large amount of heat. Without mechanical cooling, the air temperature in the kitchen can be over 30 °C during summertime, which increases discomfort (Heinonen 1997: 396). The heat flux generated by the gas fire raises the temperature of the air adjacent to this region (Xing *et al.* 2005: 3641).

While firewood is not a major source of contamination, wood is an important kitchen fuel and one of the least regulated sources of emissions. Burning wood releases pollutants; the main parts of the smoke are CO_2 and CO (Jha 2005: 1). CO_2 levels affect the occupational health of kitchen workers and help to understand the nature of thermal environments and heat stress amongst workers in commercial kitchens.

2.11.1 Equipment and kitchen heat

The Electric Power Research Institute identifies six most common types of major cooking appliances with the likelihood of their applications in various food service establishments. The researcher observed that these cooking appliances are commonly found in most restaurants in the study area. Haruyama *et al.* (2010: 135) report that heat was much higher in LPG kitchens than in electric ones with mean ambient temperatures of 29.6 °C vs 25.7 °C respectively. According to Tanaka (2006: 85), the mean WBGT in gas-fuelled kitchens was expected to induce hyperthermia among workers. Overall, the work environment in kitchens using induction cookers was more comfortable and safer, than in kitchens with LPG stoves (Wong *et al*. 2011: 750). As regards, Rabeiy (2018: 1) reports that WBGT index in Egypt indicated that the mean value of heat stress in bakeries reached 31.6 °C, exceeding the threshold limit value of 28 °C and action limit (25 °C) recommended by American Conference of Government Industrial Hygienists as per Spellman (2006).

Appliance use in kitchens are not constant. Zhang *et al.* (2010: 3.15) posit that an appliance will not be used everyday. In many food service operations, appliances are powered up as soon as preparation starts. The researchers add that the amount of time each appliance is utilised for cooking depends on the number of meal periods and the number of meals served. Therefore, it is implied the larger the volume of meals cooked, the higher the use of appliances utilised increasing heat in kitchens and heat stress risks among food service workers.

2.12 Management of thermal comfort

According to Xiang *et al.* (2014b: 90), many ecological studies have revealed that without adequate heat dissipation, extreme heat exposure leads to an increase in core body temperature and result in HRI. Physical exertion is common among the occupations mentioned in 2.11 in Appendix 1. Exertional heat illness (EHI) affects the lives of security forces, sportspersons and employees and is an incessant cause of illness among the apparently healthy and active population (Carter *et al*. 2005: 1341).

However, both commercial and non-commercial enterprises often have little incentive to proactively incorporate heat adaptation into decision-making or innovation (Richter *et al*. 2016: 8). This inertia could be attributable to policy gaps or simply the failure of management to plan long-term. Regrettably, the researcher feels that collective responsibility for safety and human health foster vague duty for individual action.

2.12.1 Capacity for preventative behavioural control measures

Behavioural control measures aim to diminish exhaustion, maximise endurance and enable sustained activity over the workday. Early study of McCollough (1973: 32) observes that bio-cultural adaptation behaviour among the Yucatan during work in a hot climate prevents heatstrokes and heat cramps. Besides, the practice of consuming indigenous food with specific heating and cooling effects is reported in Latin America, Morocco, Southeast Asian countries as well as India (Lambert 1992: 1069; Pool 1987: 389). Most Asians consider certain foods ‘hot’ and ‘cold’. Foods such as cucumber, watermelon, yoghurt, ice-cream and orange are considered cold and consumed to cool the body (Chavez 2011: 264). It seems humoral beliefs in South Asian countries are influenced by Ayurvedic medicine: an extremely important concept of maintaining a balance in the body. Lundgren-Kownacki (2018: 49), reports that in Chennai (India), buttermilk is widely consumed among workers as a traditional way of mitigating heat strain.

Self-pacing and rest breaks are traditional cultural practices including napping, pacing and wearing of wide-brimmed hats have been useful approaches for personnel to regulate and safeguard themselves from extreme heat in the past (Brake and Bates 2002: 130). The authors further suggest that the standard daytime difference in the core body temperature, which is comparatively lower at nightfall, contributes to the lower risk of HRI on the night shift and hence kitchen workers at evening shift are exposed to lesser heat strain due to cooler temperatures in the evening.

Budd (2008: 20) suggests that HRI are likely to progress when behavioural responses are not permitted because of military rules, business pressures, team effort, or personal motivation. The knock-on effects include increased accidents and negative influences on worker behaviour such as anger leading to rash acts due to heat stress (Schulte and Chun 2009: 564). Similarly, high temperatures coupled with long hours in the kitchen are responsible for death among chefs (Totsky 2006: 1).

2.12.2 Amelioration of conditions impacting on heat illness

Reactive behavioural adjustment to heat adaptation dominate studies seeking improvement in conditions that impact on heat illness (Figure 2.3). Whilst there are proactive practices for human heat adaptation in the workplace, literature mentions are sparse. However, Bates and Schneider (2008: 9) observe mandatory hydration and thermal work limit in the workplace. Nikolopoulou and Lykoudis (2006: 1464) also raise the issue of physical adaptation that takes account of changing environmental conditions.

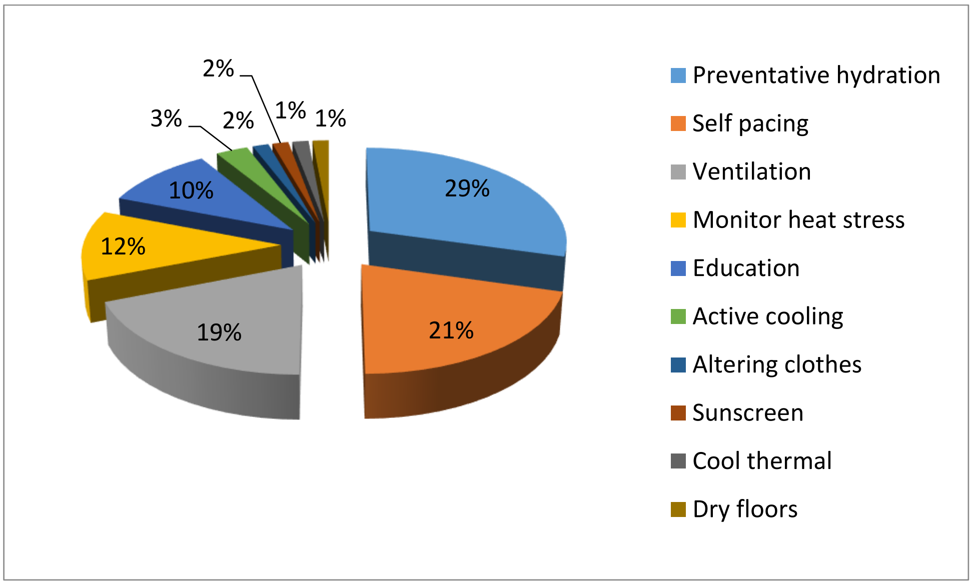


Figure 2.3 Amelioration conditions influencing heat illness (by researcher)

Of 46 selected reactive behavioural adjustment investigations studied in this study, 20 studies strongly favour preventative dehydration (Appendix 1). Preventative dehydration seeks to replace water timeously. Water that is isotonic and cold according to Bates and Schneider (2008: 9) and a rehydration solution and cold water according to Cortez (2009: 1) clearly advance the cooling of the body and prevents dehydration. Additionally, drinks containing caffeine or sugar to improve hydration status should not be used (Bates *et al.* 2001: 30, Bates and Miller 2008: 6). In another line of enquiry, Nolte *et al*. (2011: 1233) confirmed that trained athletes in South Africa ran safely in extreme dry heat (44.3 °C) when drinking water ad libitum while maintaining the serum sodium concentration.

Drinking large quantities of water can lead to frequent urination, which requires adequate toilet facilities for workers (Biggs *et al.* 2010:13). On the other hand, some workers consciously avoid drinking water due to the lack of toilet facilities, and for other workers, it was time management issues (Morioka *et al.* 2006: 474). Kitchen workers are also likely to avoid frequent visits to toilets due to the above-stated reasons, as well as reasons of hygiene, thus leading to dehydration. This is likely to increase heat strain among cooks, bakers and dishwashers.

Tian *et al*. (2011: 4) found that acclimation training could improve the adaptability of the human body to extremely hot environments. The concept of acclimation of indigenous miners in gold mines of South Africa lies in the pioneering studies of Wyndham (1964: 62). However, Mcpherson (2011: 47) claims that South Africa is the only country that provided formal acclimatisation for the majority of recruits into deep and hot mines.

Despite their high heat exposure some workers in enclosed workspaces were found to have no access to rooms with cold air (Li *et al.* 2012; Mirabelli *et al.* 2010; Inaba and Mirbod 2007; Morioke *et al.* 2006; Maeda *et al.* 2006). In addition, existing HVAC facilities cannot be consistently relied on to meet the requirements of heat load in different occupational settings. Opening windows where feasible, improving air circulation by using fans, installing adequate extractors for fumes and gases, air-conditioning work areas and restrooms to reduce ambient temperature and thermal load on workers are advanced in Appendix 1 (Unison 2014: 6).

Self-pacing, rest and change of work hours are advanced in 13 studies as advocated in Miller *et al.* (2011: 548) for its avoidance of physiological strain by way of work rate adjustments and consequent retention of normal body temperature. It has been suggested that work hours should be reduced in extreme environments.

Thus the monitoring of worker discomfort, inability to work and perform well (Brake and Bates 2002:130; Balakrishnan *et al.* 2010: 8) and the efficacy of heat interventions (Ayyappan *et al.* 2009: 1) can be set to counter heat related illness (HRI). Gubernot *et al*. (2014: 1786) reason that protective measures can be applied before illness occurs. The authors add that climate change advance adaptations and prevention measures for heat disorders.

Several authors recommend educational programs and awareness among workers to manage HRI effectively (Appendix 1). Jackson and Rosenberg (2010: 207) state that workers must understand the risks of heat illness to the extent that they take measures to prevent them.

Additional design propositions in the sampled studies that improve conditions leading to heat illness range from the wearing of cool thermals for steelworkers to frequent clothing change and the use of sunscreen for traffic controllers (Inaba and Mirbod 2007: 98). Haruyama *et al.* (2010: 137) found that by simply maintaining dry floors, work areas with high heat and humidity such as commercial kitchens could also reduce heat stress. Researchers from the USA and China have developed a heat-rejecting film that could reflect 70 % heat from sunlight in a building's windows (Chu 2018: 1). Exterior-facing windows can be covered in this film embedded with tiny thermos-chromic to reduce the building's air-conditioning costs by 10 %. Kitchen windows can be covered with film to reduce heat in kitchens.

The foregoing measures and recommendations to ameliorate the impact of heat illness have not been viewed in isolation in the literature. It is also observable that workers in poor economies were provided with inadequate measures if any, to reduce heat strain. None of the studies continue into a follow up to confirm the implementation of recommendations to improve the work environment and reduce the thermal stress of workers.

2.12.3 Prospective designs to improve conditions that impact on heat illness

Creating a win-win situation for worker health and work performances is the way forward. On the one hand, there is the vulnerable health of workers, and on the other hand, the researcher feels that there is no specific provision made for employees to decrease exposure from the risks in the South African legislation. OSHA and NIOSH cobranded an information sheet on safeguarding workers from HRI. Since 2011, OSHA has advocated a countrywide awareness and outreach campaign on heat illness and prevention movement in USA to draw attention and educate workers and employers about the dangers of working in the heat and preventing HRI (NIOSH 2015: 102). Figure 2.5 traces the path to severity of heat illness.

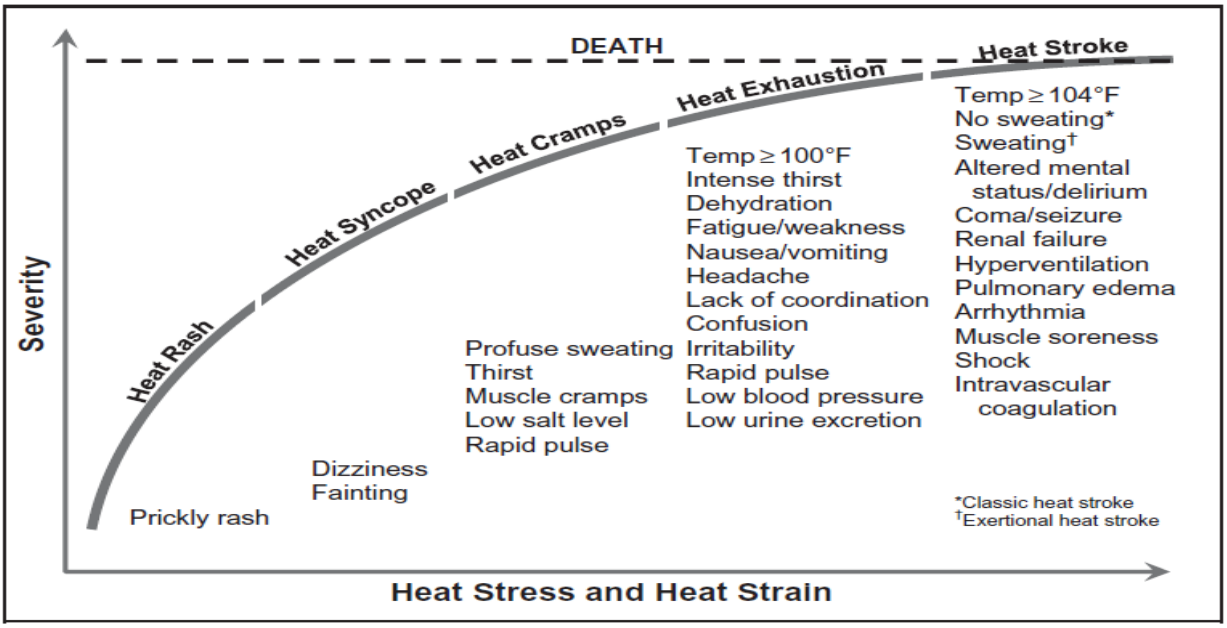


Figure 2.2 Heat stress and heat strain (adapted from Jackson and Rosenberg 2010: 206)

Adaptation strategies that account for natural variability in climates can be regional at best, but mostly local take account of occupational settings and increase attention to worker well-being and work performance. Due consideration should be given to cultural and regional diversity, personal differences and adaptability. Adaptation using a single metric is therefore elusive and impedes comparisons between possible adaptation options.

Adaptation policies can help to manage risks by reducing vulnerability and increasing resilience to impacts to mitigate the drawbacks.It seems that long-term adaptation rather than reactive measures as a response to heat will successfully lead to positive worker health.

The researcher found that there is a dearth of psychological studies of the risk of HRI in occupational settings of workers. Recent studies on thermal adaptation concerning Africa and more specifically, South Africa are especially lacking. Moreover, despite the maturity in the heat prone occupational sectors, exhaustive studies of worker heat adaptation are lacking.

A simplified model of HRI conditions with associated symptoms is indicated in Figure 2.5. Heat stress can be experienced with the onset of heat rash, dizziness and fainting. When the body temperature increases to 40 °C (104 °F), heatstroke can occur. The review of literature elicits a combination of approaches for HRI prevention. Common in these combinations are practices that encompass: monitoring hydration status and preventative hydration, provision of adequate potable cool water and rehydration fluid; ventilation and air cooling; self-pacing and rest in shade; change in work hours and activities and restricting work hours; improving acclimatisation and training and health education; monitoring discomfort and work performance.

2.13 Conclusion

This chapter illustrates that the adaptive heat model refutes ASHRAE'S narrow range of temperature for thermal satisfaction. The PMV model appears not to apply to hot environments such as commercial kitchens and bakeries. Physiological mechanisms set limits to the worker's capacity for physical work; fatigue can set in due to hot temperatures in kitchens. Some of the factors that contribute to a worker's susceptibility to heat stress include medical conditions, increasing age, fitness, dehydration and individual ability based on genotype to acclimatise to extreme temperatures. Currently, the occurrence and degree of extreme heat exposure in different employment sectors prove that there is a decline in implementing effective strategies and alleviation schemes in most countries. Preventing occupational heat stress is especially important in developing countries. The next chapter will discuss the significance of ventilation and humidity in commercial kitchens.

CHAPTER THREE

VENTILATION AND HUMIDITY

3.1 Introduction

This chapter will examine the role of ventilation in providing comfortable and productive working conditions and protecting the health of kitchen workers. Ventilation in kitchens is desirable to control air contaminants, humidity and temperature. Natural and mechanical ventilation (MV) that affects IAQ include airflow, kitchen space, cuisine and humidity will be discussed, initially. In the penultimate section, an in-depth examination of air composition affected by cooking processes, fuel, oil, cooking methods, extraction rates, canopy size, filters and capacity of hoods is undertaken. This is followed by a critical look at humidity and its effects in kitchens.

3.2 Indoor air

Human beings spend most of their time indoors and it is, therefore, essential that indoor air is free from pollutants (Moya *et al*. 2019: 299). The term "indoor air" refers to the air that is inside confined spaces, such as homes, offices and schools. ASHRAE standards impart evidence on the permissible levels of pollutants in the air, which relates to the health and comfort of building occupants (Tham 2016: 637). Sassi (2017: 167) claims that the introduction of improved energy performance standards has resulted in a better insulated and more airtight building and that natural and decentralised building ventilation systems provide good air quality.

The indoor environment is dynamic and is further affected by several parameters including HVAC systems; the presence of human beings and pollution sources such as office equipment and cleaning procedures (Moya *et al*. 2019: 299). These parameters cause air pollution and it is necessary for a holistic approach directed at efficient removal of impurities from indoor air. The health effects of air pollution are aggravated when polluted air takes a long time to be flushed out of the cooking area (Ruth *et al.* 2013: 151). These authors also find that efficient ventilation made a significant difference in the IAQ of the cooking environment by reducing carbon monoxide (CO) and minute particulate matter (PM) by about 50 %.

3.3 Airflow and thermal comfort predilections

The thermal comfort inside a building are influenced by ambient temperature, BMR of a worker, radiant temperature, humidity and airspeed (Babu and Suthar 2020: 140). The human body perspires heavily during intense work and as sweat evaporates, it absorbs latent heat from the body and cools it (Faizal *et al*. 2011: 1). Most people prefer a relative humidity (RH) of 40 % to 60 %

and air motion also plays a vital role in human comfort as it improves heat loss by both convection and evaporation. André *et al*. (2020: 990) claim that in tropics, increased air velocity is a useful approach to boost thermal comfort.

People feel comfortable at an airspeed of about 0.25 m/s or 15 m/min (Cengel and Boles 2007: 729). Boduch and Fincher (2009: 3) claim that airflow slower than 0.5 m/s feels pleasant whilst higher airflow rates (1.02 m/s or 200 fpm) can provoke distraction and, above 1.02 m/s cause annoyance. In a similar vein, Bridger (2003: 254) suggests that at lower temperatures, air velocity less than 0.1 m/s tend to cause a sensation of staleness and stuffiness and airspeeds greater than 0.2 m/s may be perceived as drafty. Airspeeds of 0.2 m/s to 0.5 m/s will help in body cooling in hotter conditions, especially when RH is high (Bridger 2003: 255). In contrast, Faizal *et al*. (2011: 8) recommend air velocities less than 0.9 m/s. Yan *et al*. (2020: 1) report that airspeeds of more than 1.0 m/s have a cooling effect in the air temperature above 33.5 °C in hot-humid regions. Zhai *et al.* (2015: 178) recommend airspeed of 1.2 m/s at 30 °C with a RH of 80 % which exceeded the upper limit set in the ASHRAE Standard 55 (0.8 m/s).

The ASHRAE Standard 55 recommends temperatures between 20 °C to 25 °C for buildings without significant air movement if the maximum velocity does not exceed 0.2 m/s (ASHRAE Standard 55 2004: 14). Natural ventilation with higher airspeeds of 0.8 m/s, for a maximum temperature of 28 °C, is sufficient (Rupp 2015: 188). The association between temperature and airspeed, together with ventilation, will help understand indoor kitchen environments in Durban. Simone *et al*. (2013: 1007) do not draw any distinction between velocities recorded in quick-service restaurants (QSR) and other food service operations. It seems QSR have smaller areas to be ventilated and higher air velocities due to stricter legislation in the United States of America.

However, SA Weather services (2020: 2) reports that the average outside wind speed varies from 0.1 to < 8 m/s in South Africa with a mean wind speed of 5.14 m/s. On the Beaufort Wind Scale, humans feel the wind when the speed exceeds 1.5 m/s. These winds can influence thermal comfort and the effectiveness of ventilation in kitchens with fenestrations. According to Greening (2010: 4), Durban weather is associated with north-easterly winds, high temperatures and high levels of humidity. The mean daily RH levels vary between 54 % to 71 % (SA Weather services 2020: 2). Such high humidity levels can cause thermal discomfort and require higher airspeeds to improve ventilation in kitchens (Rahmillah *et al*. 2017: 5). Sufficient natural ventilation is nonetheless vital to prevent dampness in the air and reduce pollutant concentrations effectively for indoor thermal environments in hot and humid climates in the absence of MV (Walker 2016: 1).

3.4 Natural ventilation

According to Wong *et al*. (2020: 165), natural ventilation (NV) plays a vital role in improving indoor thermal comfort and air quality. NV has great potential to create desirable IAQ and reduce energy consumption in buildings where passive cooling of the internal environment occurs (Walker 2016: 1). Atkinson *et al*. (2009: 27) declare that it is beneficial to utilise the natural wind patterns of a location to increase the potential benefits of natural ventilation. However, Timerbaeva (2010: 6) explains that natural ventilation is only present in small or old facilities and used rarely in present times.

NV plays an important role in providing better IAQ, thermal comfort and energy-saving in buildings (Muhsin *et al*. 2016: 1). The natural forces of wind and buoyancy deliver fresh air into buildings alleviating odours and increase thermal comfort in indoor environments (Walker 2016: 1) and (Yin *et al*. 2019: 13). According to Asfour (2015: 7), NV has a high potential for improving thermal comfort in hot climates in implementing wind-induced ventilation. Wind-induced NV is created by wind pressure differences, a system to reintroduce air in a building by creating airflow to dispel heat from the human body to the environment (Lim *et al*. 2013: 332). Revit (2018: 1) claims that stack ventilation uses such air pressure differences due to height that pulls air through the building. Warm air inside the building will flow out through fenestrations at a higher level of the building fabric while cooler, denser air will replace it (Al-Obaidi *et al*. 2014: 234). Stack ventilation could function naturally without the necessity for any pressure.

As with mechanical ventilation, NV is unsuccessful in decreasing the dampness of inbound air. This prevents the potential efficiency of NV in tropical environments even though most historic buildings were ventilated naturally (Walker 2016: 1). NV of buildings, according to Walker (2016: 1), depends on the environment, structural design and an individuals's conduct. The author contends that it provides an economical ventilation rate, due to drafts and large fenestrations such as doors, windows and vents. The temperature and air velocity distributions within a building due to natural convection can be complex, especially when external factors such as wind patterns and directions influence the flow patterns within a building (Stoakes 2011: 365). Al-Obaidi *et al.* (2014: 232) report that individuals occupy buildings almost 87 % of time, which has implications for kitchen design. Openings between rooms such as transom windows, louvres, grills, or open-plans are techniques to complete the airflow circuit through a building.

Hyun *et al*. (2008: 312) contend that NV has not received significant attention as it is difficult to quantify and challenging to predict natural ventilation in a building because of the complexity and unsteadiness of the wind. Nonetheless, Gough *et al*. (2018: 246) claim that NV becomes less effective in urban areas because its performance in buildings is affected by factors such as opening shape, size, location and fluctuations in wind direction and wind speed. Moreover, Adamu (2013: 30) cautions that natural ventilation is beset by challenges such as the irregularity of airflow due to the wind forces being unreliable. Purpose-built design strategies to enhance NV include windows, doors, solar chimneys, wind towers, trickle ventilators, wind catchers, venturi-shaped roofs, saw-tooth roofs and atria (Muhsin *et al*. 2016: 1).

3.5 Preventative measures for inadequate ventilation

The primary task of kitchen ventilation is to remove sufficient convective heat and contaminants from the occupied zone with minimal airflow rate (Han *et al.* 2019: 3). Kosonen (2006: 2) adds that a properly designed and located exhaust hood is essential for effective kitchen ventilation. The ventilation system also brings the air to refresh the working place by replacing the exhausted air. Boduch and Fincher (2009: 7) and Alexandrova (2009: 4) suggest the following measures to prevent poor air quality and inadequate ventilation:

- filtering air;
- maintaining sufficient air replacement and ventilation rates;
- appropriate sealing of any openings to unfiltered air or gases and including subterranean spaces;
- improved maintenance of air quality equipment can maximise their efficacy;
- installing HEPA-filters and electrostatic precipitators to collect grease vapour and improve PM efficiency; and
- UV-light technology or cold plasma, which is a new filtration system that can kill 99.99 % of pathogens in a single pass.

3.6 Architectural features suitable for kitchen ventilation in Durban

Nicol and Roaf (2017: 148) insist that Architectural Science holds a mandate for the universal restoration of NV in buildings to make it habitable during power failures, especially during heatwaves. Sada and Salih’s (2019: 255) experimental work indicates an improvement of IAQ by source control, suitable purification, and the use of a ventilation system. Additionally, openings located at opposite walls are more effective for cross ventilation (Asfour 2015: 9). Van Hoof *et al*. (2017: 127) conclude that thermal comfort can be achieved through a sensible combination of structural designs that include shades, blinds, doors, operable windows and balconies, and active technological solutions.

Four primary architectural design features will be reviewed in the sections to follow.

3.6.1 Chimney or smokestack

According to Asfour (2015: 9) heated air rises from a cavity and leaves through the top opening and induces cooler fresh air, provided by wall openings inside the space According to the author, air circulation is accelerated when prevailing wind currents pass over the chimney. Chimneys are helpful while burning solid fuels, for example, in wood-fired pizza ovens. However, an un-swept chimney increases sooty build-up, which could restrict smoke and potentially harmful emissions from escaping (Christie 2019: 1).

3.6.2 Ceiling height

The National Building Regulations (NBR) published by the South African Bureau of Standards (SABS) in 2008 (Keuter 2008: 115) and Queensland Food Safety and Public Health Working Group (2019: 17) regulate a ceiling height of 2.4 m above the floor area in kitchens. Guimarães *et al*. (2013: 75-76) show that in tropical countries, for every 20 cm reduction in ceiling height, the temperature increases by 1 °C. Haruyama *et al.* (2010: 138) report that the environment of a worker in a gas kitchen was smaller due to lower ceiling height (< 3 m)**.** As the temperature range of human comfort is small, these variations, however subtle, may cause thermal discomfort to users. Ceiling heights should be carefully considered as higher ceilings assist NV (Auckland Council 2019: 3).

3.6.3 Open-plan design

The open kitchen is becoming a hallmark of good restaurant design. The open kitchen is great for entertaining guests and an open kitchen is also a good opportunity to maximize a small space (Rankin 2019: 6) seen in some high-end restaurant. However, the key concern is to ensure proper ventilation (Gordon and Ziegler 2017: 1). NV through building fenestrations such as open-plans are techniques for cross-ventilation in a building (Walker 2016: 1). The researcher contends that open-plan design may hold value in composing indoor environmental criteria for the design of restaurant kitchens in Durban in respect of ventilation.

3.6.4 Doors and windows

Doors and open windows provide natural ventilation through openings when the long façade of the building faces the prevailing wind direction (Passive design 2018: 1). These openings help with the air movement through a building due to wind-driven technique using the natural wind force (Lim *et al*. 2013: 332). Behavioural adaptation of opening windows allows airflow and alterated temperature that may advance IAQ (Nicol 2020: 14). Even in the case of an opening located only on one side of a building, such as an open door or a window, wind-induced single-side ventilation occurs (Asfour 2015: 9). Fresh air enters through any windward opening and is exhausted from any leeward opening to equalise the pressure (Walker 2016: 1). Roaf (2020: 1112) states that opening windows is essential. However, the City of Milwaukee (2020: 571) states that all living rooms should be provided with a minimum of a single window or skylight that is operable or any other mechanism that will sufficiently air the room.

3.7 Artificial ventilation

Without artificial ventilation to provide fresh air, moisture, odour and other impurities can accumulate in a building. Mechanical ventilation (MV) systems circulate fresh air using ducts and fans and do not depend on airflow through fenestrations (Energy Star 2007: 1). However, MV can break down and require repairs, frequently. It can be expensive to install a mechanical or other artificial ventilation and there is always an after-expense for maintenance, according to the appliances adopted.

3.7.1 Air curtains

Air door consist of a forceful blower that creates an undetectable obstruction, which efficiently divides one environment from another (Airtecnics 2020: 1). Air curtains, or air doors, mounted at entrances activate automatically when kitchen doors open and deliver a strong, stable air stream blowing downwards (Black 2019: 1). Food service operators commonly use air curtains to separate indoors from outdoors, cooling and deter insects. Manshoor *et al.* (2014b: 36) installed an air curtain in front of a kitchen hood, as the existing hood may not exhaust the smoke and heat in the kitchen.

Zhou *et al*. (2016: 99) found that the CO_2 levels reduced with an application of air curtains in the breathing zone. The air temperature can be reduced during the summer to improve occupant thermal comfort and decrease pollutant concentrations to improve air distribution.

3.7.1 Air-conditioners and coolers

Kitchens with air supply systems without a cooling unit seem to do little to reduce discomfort during warm summers where the air temperature rises above 21 °C. The HVAC units can facilitate IAQ, odour, dust and cooler temperatures in the kitchens. As per Quest Climate (2020: 2), air-condition systems protect kitchens from damp and other moisture-related issues but they are extremely inefficient for removing moisture. Coolers can decrease air temperatures at a fraction of the cost of refrigerated cooling (Newair 2019: 2). Ideally, commercial kitchens should have at least 20/25 air changes per hour to deal with heat (Intelligent Cooling Solutions 2019: 2). Air-coolers, help to air-condition kitchen spaces. In addition to purifying and refreshing space, it also dehumidifies a moist kitchen. John and Liu (2020: 20) indicate that a high level of thermal mixing of the conditioned air with the room air have been proven to correlate with high levels of occupant thermal comfort in mixed air systems.

Table 3.1 Review of extraction systems by the researcher

Source	**Passive ventilation (PV)**	**Active ventilation (AV)**	**Hybrid ventilation**	**Others**				
	Natural	Mechanical		Dilute	Displacement	LEV	DCV	Mixing
ASHRAE (2004)	√	√	√ PV + AV					
Yuan *et al.* (2013: 61)					√			√
Lin (2014: 41)								√
Daaboul *et al*. (2017)			√ PV + AV					
Jimoh (2017: 55)	√	√	√ PV + AV					
Timerbaeva (2010: 3)			√ PV + AV	√	√			√
Zolotareva (2011: 13)	√	√	√ PV + AV					
Hou *et al.* (2012:1100)							√	
Ng (2012: 1)					√ LEV			
Cao *et al*. (2014: 173)		√	√MV + DV	√	√ LEV	√	√	√
Zhou *et al.* (2019: 182)					√ PP			
Manshoor *et al*. (2014a: 1)					√			
Li *et al.* (2012:150)					√			
Mikeska and Fan (2015)		√		√				
Clark (2012)					√ PP			
Southern California Edison (2009: 1)							√	
Kosonen (2010: 1)					√			
Velux (2017)			√					
AOM (u.d)					√			
Key: DV-Displacement ventilation LEV-Local Exhaust Ventilation DCV-Demand controlled ventilation MV-Mixing ventilation PP-Push-pull ventilation								

Table 3.1 lists the different types of extraction mechanism in the kitchen environment. Hybrid ventilation seems common with seven studies (37 %) mentioning it. However, displacement ventilation seems to be the trend as studied by several authors (52.6%). The emerging technology

in respect of demand controlled ventilation (DCV) in commercial kitchens is 16 %. According to Better Buildings (2015), the energy and cost savings of a DCV is determined by a variety of factors including cooling and heating loads in a kitchen. Once kitchens are constructed as green buildings, natural ventilation in kitchens will be taken earnestly, well ventilated kitchens will ensure that this heat is not transferred to other parts of the buildings (Master Builders 2021: 6).

3.8 Mechanical ventilation

According to Keuter (2008: 115), the National Building Regulations and Building Standards Act, no. 103 of 1977 in South Africa (as amended) controls the approval, design, location and testing of artificial ventilation systems in buildings.

All commercial kitchens must use mechanical ventilation (MV) systems to create a comfortable working environment that promotes health and safety at work as well as good hygiene and food safety (Advanced Control Solutions 2018: 1). The outside air is drawn into the kitchens due to a lowered pressure balance (Atkinson *et al.* 2009: 7). Commercial kitchens often seem to use this type of dilution ventilation. Yuan *et al.* (2013: 61) posit the adoption of mixing ventilation to cool the space in conventional kitchens that may not be the best fit since high discharge velocity creates undesirable air movement.

In a positive pressure system as in a room, the room air leaks out through openings. In a balanced MV system, air supplies and exhausts are adjusted to meet design specifications. Mechanical means can provide make-up air, but it should be fresh and unadulterated from the outside (Electricians Forum 2017: 2).

3.8.1 Whirlybird or roof turbine

Whirlybird are turbo ventilators driven by natural wind force (Al-Obaidi *et al*. 2014: 234) and ideal to ventilate buildings. It is a heat escape port located high in the building; the primary motive forces being stack effect and wind induction. It seems obvious that the installation of these whirlybirds is appropriate in Durban kitchens due to natural ventilation from wind speeds. A distinctive feature of a whirlybird is that it is operational even in the absence of wind flow due to the stack effect (Jadhav *et al*. 2016: 196).

Whirlybirds are widely installed in Taiwan to enhance building ventilation (Shieh *et al.* 2010: 2341); northen Taiwan belongs to a sub-tropical climate zone, very similar to Durban. An appropriate combination of whirlybirds and natural ventilation will immensely help IAQ and reduce dependence on cooling devices (Shieh *et al.* 2010: 2341). Correspondingly, wind vents can provide expected volume of clean air even at comparatively low wind speeds (Hughes and Ghani 2008: 1651).

3.8.2 Fans

A ceiling fan in the kitchen helps remove unwanted odours by dispersing them while providing much needed cooling comfort (Best Ceiling Fans.net u.d) in the general areas in a kitchen. Ceiling fans deliver airflow during the hottest time of day and provide thermal comfort (Nicol 2020: 14) and (Parkinson *et al.* 2020: 1). Arens *et al.* (2020: 6) recommend the fan aim at different parts of human body and provide airspeed ranging from 0.36 - 0.8 m/s (70.9 - 157.5 fpm).

Ceiling fans with retractable blades can be used in kitchens; however, table fans are preferred (Yunghans 2010: 1). On the other hand, reverse flow fans in kitchens remove air contaminants by pulling them out through an exhaust fan (Fantech 2019: 1). Present *et al*. (2019: 26) find that ceiling fans have the potential benefits of downsizing HVAC equipment. Ceiling fans increase occupant comfort and decreased energy use. Schiavon *et al*. (2016: 1) conclude that fans improved IEQ in tropical climates.

Tower fans are a good cooling solution in bars, cafes and restaurants as the device fits perfectly into the corners without occupying significant amounts of space (Your Towerfan 2017: 1). Honeywell (2019: 2) claims that tower fans discharge air perpendicularly that spreads across a broad area. Tower fans have a simple dust filter and are compact in design.

3.8.3 Ventilated ceiling system

The Ventilated Ceiling System consists of a modular exhaust pod installed in a grid. The Ventilated Ceiling System is individually custom-sized and engineered for light and medium-duty commercial cooking applications (Halton 2016: 1).

According to Vianen (2017: 2), the flat ventilated ceiling system can be installed where no direct exhaust is required. Halton (2016: 3) observes that the capture jet ventilated ceilings claim to optimise hygienic conditions, and health and safety. These features appear to be desirable in commercial kitchens.

3.9 Heating, ventilation and air-conditioning system

Effective emission control within commercial and industrial production kitchens, has always been a cause of great concern for hospitality operators and kitchen workers (Han *et al.* 2019: 1). The type of space plays a key role in determining the necessary ventilation requirements.

A well-run kitchen requires a well-designed HVAC system (Air2o 2019: 1). The heat loads generated in a commercial kitchen from the cooking activities contribute to the majority of heat gains to the space. Li *et al.* (2019: 505) claim that there are two widely applied ventilation modes: mixed-mode (MM) ventilation and displacement ventilation (DV). Kosonen (2015: 1) reports that a low-velocity DV system allows for a decline in exhaust airflow by 15 % compared to a conventional mixing ventilation system. Hence, Yuan *et al.* (2013: 61) contend that DV can maintain a thermally comfortable environment, and a low percentage of dissatisfied people, and may provide better IAQ compared to MM.

According to Xpelair (2019:2), stratum ventilation is appropriate for light-duty kitchens, described by Lin *et al.* (2014: 41) as the pumping of clean air in a breathing zone. Ventilation in medium, heavy and extra-heavy-duty is discussed later in section 3.10.4. Sherman (2004: 1) claims that ASHRAE Standard 62.2-2003 recommends a balanced ventilation system that uses two fans with separate ducting systems, one to supply fresh air and one to remove stale air from the building.

Commercial kitchens can have a single ventilation method or a combination of methods in different areas of a kitchen. A strategic design to use natural ventilation for the majority of occupied hours can be supported by mechanical devices with maximum cooling (Breathing Buildings 2020: 1). Mixed-mode (MM) ventilation facilitates greater thermal comfort levels and worker satisfaction (De Vecchi *et al.* 2017: 672) although the mean thermal perception in air-conditioned space was considerably lower than that in NV and MM spaces.

3.10 Kitchen Ventilation Classification

Zhang and de Dear (2019: 10) report that workers' sensitivity to temperature, humidity and airflow significantly vary between different ventilation modes. A properly designed commercial kitchen ventilation system will increase the well-being of the kitchen workers (Greenheck 2020: 2). The type of cooking, the scale of cooking and the location of the kitchen premises dictate the design of a kitchen ventilation system (Nisbets 2019: 1).

Whilst each country may have a variation in standards and codes adopted, the classification of ventilation systems facilitates a common basis for comparison of establishments for environmental ergonomics in kitchens. Hence, kitchen ventilation classification is crucial for evaluating IAQ. This better enables different types of menu, preparation, cuisine and the volume of food preparation while managing the production of heat and thermal plumes.

3.10.1 International Mechanical Code (classification of commercial kitchens)

According to International Mechanical Code (IMC) International Code Council (2017: 51) as supported in ASHRAE 62.1 (2013:17), kitchens are classified based on the type of equipment used in the kitchen operations that are highly pertinent to the type of cuisine prepared.

This classification specifies the appropriate type of ventilation hoods to be installed and the exhaust ventilation rates to be maintained for establishing thermal comfort, good air quality and acceptable humidity in commercial kitchens. Specifications in the classification of ventilation are necessary for contributing to controlled airflow rates that affect IEQ (Heinonen 1997: 124).

To control IEQ in commercial kitchens, as per Twin city Fan (2018: 6), the Department of Fire endorses Type I or Type II hoods to be mounted over cooking equipment as per the municipality by-laws of most countries. Commercial kitchen extractors are designed to trap and contain vapours and emissions. It is a requirement that extractors are in commission during the food preparation (Twin city Fan 2018: 6). Both types of hoods seem relevant in South Africa as the cuisine covers a wide range of cooking styles.

Clark (2012: 55) states that Type I hoods are fitted over medium-duty, heavy-duty and extra-heavy-duty cooking appliances; recognised as Class 1 Cooking Operations for grease-laden vapours (City of Penticton 2013: 2).

Type II hoods are installed above dishwashers and light-duty appliances that produce heat or humidity but not grease or smoke (Southern California Edison 2009: 2). These operations are recognised as Class 2 Cooking Operations for steam and heat removal (City of Penticton 2013: 3).

3.10.2 Class 2 Cooking Operations

According to Penticton (City of 2013: 2), Class 2 cooking operations include equipment if they are > 6 kilowatts. Several equipment belonging to this category seem to be common in Durban restaurants such as closed pizza oven, conveyor pizza oven, induction cooker, boilers for potatoes, pasta or rice that may increase humidity.

3.10.3 Class 1 Cooking Operations

City of Penticton (2013: 4) specifies that class 1 cooking operations and equipment are those outside the scope of Class 2 and other classes. Commercial type equipment as well as domestic-type equipment used in a commercial food establishment. Most of the equipment listed here seem to be present in Durban kitchens.

3.10.4 Kitchen equipment classification

The classification of equipment discussed is relevant for this investigation as the heat and fumes produced affect ventilation which is an integral part of IEQ in kitchens. Heinonen (1997: 395) and Clark (2009: 21) concur that ventilation systems are selected on the heat output from the cooking appliances. The loads will help understand the nature of indoor environmental criteria for the design of kitchens in Durban in respect of ventilation (Table 3.2 page 53).

Similar to Clark, Greenheck (2020: 3) has a dissimilar classification for the appliance when compared to ASHRAE. Gas ovens and pizza ovens are classified as light-duty appliances and combi-ovens are labelled as medium-duty equipment. The current study has classified pizza conveyor ovens as light-duty and then subsequently adopted ASHRAE's (2013: 17) labelling of appliances. An arrangement of heavy-duty, medium-duty and light-duty cooking appliances under a single hood requires extraction rates of a heavy-duty appliance (Clark 2012: 56).

High-efficiency extractors are a requisite to contain emissions and sustain good IAQ in kitchens (Han *et al*. 2019: 2). According to the California Energy Commission (2003: 2), cooking appliances are categorised subject to the strength of the thermal plume, the amount of grease and smoke produced. Kosonen (2005: 1), on the other hand, claims that the commercial kitchen equipment is categorised according to the cooking appliance convective heat output, the area of exposure, distance of the extraction unit from the cooking equipment and the effect of the general ventilation for the contaminant removal efficiency.

Table 3.2 Equipment Classification and kitchen load

Equipment Kitchen Load	Light-Duty Equipment 204 °C to 232 °C	Medium- Duty Equipment 204 °C to 232 °C	Heavy-Duty Equipment 316 °C	Extra-Heavy Duty Equipment 371 °C
IMC (2015)	Ovens Cheese melters Re-thermalizers Steam-Jacketed Kettles Compartment Steamers	Griddles Fryers Pasta Cookers Tilting Skillets Braising Pans Rotisseries Conveyor (Pizza) Ovens	Open-Burner Ranges Electric/Gas Underfired Broilers Salamander (Upright) Broilers Chain Broilers Wok Ranges	Appliances using Solid Fuel (Wood, Charcoal, Briquettes and Mesquite) to provide all or part of the heat source
	Light	**Medium**	**Heavy**	**Extra-heavy**
Greenheck (2020)	Gas & Electric Ovens Gas & Electric Steamers Gas & Electric Ranges Food Warmers Pasta Cookers Pizza Ovens Smoker Rotisserie	Combi-Ovens Gas & Electric Fryers Griddles Tilting Skillets Tilting Braising Pans Grill Hibachi Grill Salamander	Upright Broiler Electric Char-Broiler	Gas Char-Broiler Mesquite Infrared Broiler Lava Rock Char-Broiler Wok Chain Broiler

Though the efficiency of hoods has been tested by the Commercial Kitchen Ventilation Laboratory USA, the volume of air required to be extracted can be calculated once the duct size is known. There could be a variance in the recommended exhaust rates for different kitchen loads when equated to IMC and ASHRAE (Bhatia 2012: 20). No piece of equipment creates more disagreement within the food service equipment supply and design community than the exhaust hood in all its styles and makeup air combinations (California Energy Commission 2003: 1).

In a balanced MV system, air supplies and exhaust are adjusted to meet the design specification. Air and Odour Management (AOM) (2015: 2) reports that as the plume rises by natural convection, it is captured by the hood and removed by the suction of the exhaust fan. Commercial food service hoods exhaust a minimum net quantity of air determined in accordance with Sections 507.5.1 through 507.5.5 (IMC 2015: 58). ASHRAE Standard 62.2-2016 requires a minimum airflow rate of 100 cfm or 50 litres per second (L/s). This would maintain a desirable CO_2 level and thermal comfort in kitchens (IMC 2015: 35).

According to Adam (2013: 19), the minimum required cfm per linear foot of hood for listed and unlisted hoods is given by IMC. UL Listed means that the product has been tested by Underwriters Laboratories (USA) to nationally recognised Safety Standards and is free from a reasonably foreseeable risk of fire, electric shock and related hazards. Paradoxically, unlisted hoods require higher exhaust flow rates. Manitoba (2013: 9) claims that UL Standard 710 exhaust hoods meeting the design criteria maintain desirable ventilation and humidity rates improving IEQ in commercial kitchens.

According to Kosonen *et al.* (2006: 1141), the primary guide for designing of kitchen ventilation has been the calculation of the airflow rate based on thermal plume; undersized airflow rates could lead to indoor air problems. The strength of the thermal plume is a major factor in determining the exhaust rate (California Energy Commission 2003: 2). Exhaust rate and the type of hood will inform the kitchen load and the appropriate equipment that can be installed.

3.11 Air composition

Whilst kitchen conditions in a report by NIOSH (Sateri and Finnish Society of Indoor Air Quality and Climate 2004: 42) find that 20 % of public grievances were regarding air quality and 50 % were due to poor air circulation, the present study will assess IAQ based on responses to comfort sense from drafts and workers well-being.

The well-being of workers is impacted indoors by different categories of contaminants present indoors are released by natural or human activities (Babu and Suthar 2020: 139). In this regard, kitchens have an appropriate setting for microbes to flourish. Sick building syndrome (SBS) with unknown causes may emerge, and the situation is exacerbated due to poor ventilation (Gul 2011: 91). In a restaurant kitchen, operating environments are particularly challenging, and high emission rates of contaminants are released from the cooking process (Kosonen 2005: 1). Apprehensions over indoor environment seem to have amplified during recent years due to an awareness about the significance of thermal settings, air quality, well-being and efficiency of workers.

Specifically, Yin *et al.* (2019**:** 2) state that in residential buildings, formaldehyde has been drawing attention due to its health risks, such as SBS and cancer. Commercial kitchens are likely to be licensed to operate in these buildings. Natural ventilation through window openings can remove indoor formaldehyde - a carcinogen (Gul 2011: 92). Heat and humidity speed up the emission of formaldehyde, a condition that is common to commercial kitchens.

3.12 Air quality

This section will present the factors influencing air composition in commercial kitchens. As per Marć *et al*. (2018: 2068) claim that the pollutants discharged in the indoor environment is considerably impacted by the method of cooking, the cooking equipment, the cuisine, the cooking temperature, the volume of the kitchen, the efficacy of the extraction system, and the worker density. Further consideration to be given to the nature of pollutants in the air that is affected by the food being prepared; the quality of ingredients used and the cultural factors.

The main pollutants released are CO_2, nitrogen dioxide (NO_2) and water vapour (Greiner 2020: 2). Odour can also be used as a criterion for IAQ (Sateri and Finnish Society of Indoor Air Quality and Climate 2004: 13-16). As per International Standard for Refrigeration and Air Conditioning Engineers draft (ISHRAE 2019: 24), the main source of indoor pollutants is from cooking, especially from frying or biomass. Incomplete combustion of biofuels in kitchens with inadequate air circulation increases the concentration of impurities (Ravindra *et al*. 2020: 29).

3.12.1 CO_2 Exposure

Akbar-Khanzadeh *et al.* (2010: 640) observed during a complete meal service that the level of CO_2 rises as the air-circulation rate declines. Simone *et al*. (2013: 1004) and Timerbaeva (2010: 12) therefore, concur that CO_2 concentrations indicate the adequacy of the HVAC systems performance and quality of air in each kitchen. Fromme *et al.* (2008 cited in Jimoh 2017: 53), state that measurement of CO_2 is commonly used as a convenient indicator of the building ventilation rate because human beings emit CO_2 and the concentration of CO_2 in the external environment is constant.

Khovalyg *et al*. (2020: 856) state that the IAQ can be gauged by the concentration of carbon dioxide (CO_2). According to the D2 National Building Code of Finland (2012: 8), the maximum permissible CO_2 concentration in occupancy must not exceed 1 200 ppm. This value is much higher than that suggested by Bierwirth (2018: 8) who conveys that CO_2 > 800 ppm is associated with SBS. Greiner's (2020: 1) study find that constant functioning of a stove generating 800 ppm

CO_2 without additional ventilation can cause CO_2 levels to increase rapidly to undesirable levels. Hong Kong IAQ Standards (Lee *et al.* 2001: 181), as well as per Erdmann *et al.* (2002), the Environment Protection Agency (EPA) endorses a permissible level of 1 000 ppm (1.8 g/m³) for CO_2 gas exposure. The safe levels of indoor CO_2 levels as published by Kane International Limited (2020: 1) are 350-1 000 ppm. CO_2 levels of 1 000-2 000 ppm have resulted in complaints of drowsiness and poor air.

Satish *et al.* (2012: 1671) caution that with CO_2 levels of 1 000 ppm, moderate and significant decrements occurred in the decision-making performance of volunteers. Kitchen employees face hazards such as from pollutants generated from burning of fuel and smoke from meal preparation (Juntarawijit and Juntarawijit 2017: 1). Barnes *et al*. (2006: 7) report ARI (acute respiratory infections) and poor lung function from Eastern Cape. CO_2 levels are discussed in a later section.

Not surprisingly, therefore, Institution of Gas Engineers and Managers (IGEM 2015: 7) reports that when testing installations in kitchens and the CO_2 level exceeds 2 800 ppm, the system needs to be made safe by isolation of individual appliances or increasing ventilation. In such cases, the reports add that provision of ventilation is reviewed to achieve CO_2 levels not exceeding 2 800 ppm. Yuan *et al*. (2013: 65) analysed CO_2 distribution to evaluate the IAQ index in a catering kitchen and reported that DV indicated lower levels. Demand controlled ventilation has a CO_2 sensor installed to monitor the air and switches the ventilation on or off the cooker-hood or extract fans (Smith 2015: 2), operating when the CO_2 level indicates an unhealthy atmosphere. A demand-controlled ventilation (DCV) system based on CO2 levels can maintain adequate IAQ (Shriram and Ramamurthy 2019: 805). This Standard indicates that a CO_2 concentration lower than 700 ppm but above outdoors will placate humans with respect to body odour (Bouvier *et al.* 2019: 48).

In another line of enqiry, Kim *et al.* (2011:1) posit that humans are open to dangers from meal preparation irrespective of ethnicity, lifespan and traditional food favourites as cooking is a significant part of civilisation. El-Sharkawy and Javed (2018: 1) find heavy concentration of CO_2 that surpassed Iranian permissible limits in restaurant kitchens, a major cause of growing indoor air contamination.

Besides CO_2 levels, CO and O_2 levels are monitored to indicate air quality as per Mukhtar (2018: 7). The PEL for O_2 is set between 19.5 % to 23.5 % (OSHA 1997). NIOSH (2004) defines an oxygen-deficient atmosphere as any atmosphere containing oxygen at a concentration below 19.5% at sea level. However, Rekus (1999) earlier criticised that 29 CFR 1910.146(b) defines a hazardous atmosphere which includes atmospheric oxygen concentration below 19.5 % at sea level.

3.13 Cooking process

The International Agency for Research on Cancer (IARC 2010: 311) posits that cooking fume is a word generally used to label the apparent smoke produced during meal preparation. In addition to ultrafine particulate matter, cooking methods generate aerosol oil droplets, combustion products, organic gaseous pollutants and vapour from the moisture in the food. Lee and Gany (2013: 646) confirmed that exposure to cooking oil fumes (COF) is associated with malignancy of respiratory system as these compounds are genotoxic and mutagenic. Zhao *et al.* (2019: 1937) suggest that using a suitable ventilation system along with some ancillary procedures effectively reduces COF.

3.13.1 Constituents of cooking fumes

The main source of pollutants is from the burning of fuel used for meal preparation or the cooking process itself (Kuo *et al*. 2006 cited in Marć *et al*. 2018: 2068). Cooking appliances and the process of cooking that produce these pollutants are tabulated in Appendix 2. Singh *et al*. (2016: 205) found that indoor air pollutants such as CO_2, total volatile organic compounds (TVOC) and polyaromatic hydrocarbon (PAH) emissions were above the recommended guidelines in kitchens. Frying produces significant quantities of airborne particulate matter (PM), including ultrafine particles (UFP) and fine PM ($PM_{2.5}$) (Svendahl *et al*. 2012: 230). El-Sharkawy and Javed (2018: 1) find levels of PM_{10} and $PM_{2.5}$ surpassing their IAQ recommendations while the other air pollutants were lower, but high enough to cause lasting sickness among food service workers. By-products such as free fatty acids, products of oxidation and polar compounds are formed when cooking oils are subjected to heat (De Alzaa 2018: 1). Svendahl *et al*. (2012: 230) add that cooking fumes contains several chemical compounds as will be discussed below:

3.13.1.1 Total volatile organic compounds (TVOC)

TVOC is a group of a wide range of organic chemical compounds present in ambient air or emissions. Singh *et al*. (2016: 205) found that the indoor air pollutants such as TVOC were above the recommended guidelines in kitchens. Wong *et al*. (2011: 746) state that poor lung function and higher prevalence of respiratory symptoms amongst Chinese workers in gas kitchens were associated with exposure to higher concentrations of TVOC generated during gas cooking when compared to those in electric kitchens.

3.13.1.2 Polycyclic aromatic hydrocarbon (PAH)

PAHs generated during cooking have carcinogenic characteristics (Wu *et al*. 2019: 1), predominantly from cooking practice and COF **(**Singh *et al*. 2016: 205). Solid fuels such as biomass and coal smoke contain a large number of pollutants and known carcinogens (Ezzati and

Kammen 2002: 1057). Several carcinogens were found in a study in Shanghai in a fried snack kiosk, a candy fritter kiosk and a commercial kitchen (Lee and Gany 2013: 649). Chrysene, a human carcinogen is a PAH, like naphthalene and anthracene and a natural constituent of coal tar. Alomirah *et al.* (2010:869) report that frying oil in Kuwait was high in chrysene.

3.13.1.3 Carbonyl emissions

According to Ho *et al*. (2006: 1091), cooking fumes have significant carbonyl emissions. Formaldehyde was generally the most abundant carbonyl reaching up to 60 %. Dai *et al*. (2018: 309) report that acetaldehyde is possibly carcinogenic to humans. Katragadda *et al*. (2010: 59) and Srivastava *et al.* (2010: 1343) reported carbonyl emissions such as acrolein from kitchens that used heated cooking oils. Lee and Gany (2013: 649) found increased levels of acrolein and formaldehyde in smaller restaurants where frying and grilling were common. Fullana *et al*. (2004: 5207) reported that low molecular weight aldehydes from olive oils were lower than canola oil under similar conditions with increased emission of volatiles above the smoking point. Dai *et al*. (2018: 312) found the highest total quantified carbonyls concentration in the Chinese Barbecue, followed by Szechwan Hotpot and Indian restaurants. In comparison, much lower concentrations were found in Italian, Shaanxi Noodle and Chinese Vegetarian restaurants. Indian kitchens in Durban may have similar levels of carbonyls, moreover, it appears that frying is a popular cooking method in Durban.

3.13.1.4 Particulate matter

See and Balasubramaniam (2008: 8852) posit that gas cooking is an important indoor source of particulates (PM). Deep-frying caused the largest increase in particle concentration and contained the highest proportion of nanoparticles (90 %). Deepthi *et al*. (2020: 43) observed that PM concentrations were highest during cooking of wheat roti and lowest from boiling of tea in South Indian kitchens. Mandal *et al*. (2020: 14) report a cafeteria in Delhi with a maximum concentration of PM_{10} due to continuous cooking activities. Lee *et al*. (2001: 192) found that Asian style cooking emits more PM than Western cooking; barbecue emissions had higher levels of $PM_{2.5}$ concentrations than Chinese cooking styles. Lean meat cooking produces less concentration of particles than regular meat on charbroiling (Abdullahi *et al.* 2013: 261). These findings will influence IAQ in Durban kitchens. Siddiqui *et al*. (2008: 544) established high concentrations of PM, during cooking with wood. Seltenrich (2014: A155) reports that fine and ultrafine particles (UFP) are released by heated spiral burners in stoves, electric ovens and toasters.

3.13.1.5 Gaseous oxides

Gas burners can generate NO_2 and other pollutants (Seltenrich 2014: A155). Jiang *et al.* (2012: 4435) found CO_2 concentrations of 1 420 ppm, 1 370 ppm, 1 470 ppm near gas stoves, which were higher than the acceptance criteria (CO_2 < 1 000 ppm). Wong *et al*. (2011: 746) state that poor respiratory function and illness symptoms amongst Chinese workers, in gas kitchens, was associated with exposure to higher concentrations of toxic air pollutants such as nitric oxide (NO), NO_2, CO and CO_2. NO_2 is a respiratory irritant produced in the burner and CO_2 can cause drowsiness, headache and "stuffy" feeling.

3.13.1.6 Alternate fuel emission

Levels of CO_2 and other pollutants also often exceed international guidelines as Sharma and Jain (2019: 240) report from rural India. A high concentration of CO of 29.4 ppm was found by Siddiqui *et al*. (2008: 544) in Pakistan from the use of wood cooking, significantly higher than WHO maximum guideline of 9 ppm. Barnes *et al*. (2009: 7) found that domestic use of solid fuels is linked to childhood acute respiratory infections (ARI) morbidity in the Eastern Cape of South Africa. Lee *et al*. (2001:181) found that the indoor CO_2 concentration levels at a barbecue and a hot pot restaurant were 4-6 times higher than at a dim sum and a continental canteen. The indoor CO_2 concentrations ranged from 636 ppm to 2 344 ppm. Dining areas with cooking activities had indoor CO_2 levels exceeding the Hong Kong IAQ standard of 1 000 ppm due to insufficient ventilation (Lee *et al*. 2001:181).

3.13.1.7 Frying oil safety

The European Union is the only region globally with guidelines on safety of cooking oil and frequently assess oil quality based on the total polar compound (TPCs) test (Sebastian *et al.* 2014: 420). The rejected frying oil in a Toronto commercial centre showed extremely high levels of peroxide value, free fatty acid (FFA) content and TPCs. Esfarjani *et al*. (2019: 2302) reported overdegradation of samples of discarded frying oils collected from 50 fast food restaurants in Tehran.

Test strips can also indicate the free fatty acid (FFA) content of oil as colour strips chemically react to the presence of FFA in the oil when dipped. The colours that appear on the strip are compared with the colour reference chart to determine FFA levels. The lower the p-Anisidine Value, the better the quality of fats and oils analysed (Pucci 2014: 2). The prevalence of such practices helps to better IAQ in commercial kitchens.

3.13.1.8 Other chemicals

According to National Cancer Institute (2017: 1), heterocyclic amines (HCAs) are formed when animal protein is cooked using high-temperature cooking methods, such as pan-frying or grilling over an open flame. As per Seow *et al.* (2000: 2), inhalation of heterocyclic amines, generated during frying of meat such as beef-steak may increase the risk of lung cancers among Chinese women. Chinese cooking was found to release 30 times more dicarboxylic acid than Western cuisine (Lee *et al*. 2001: 192). Air pollutants like methane (CH_4) was generated in higher amounts during gas cooking when compared to electric kitchens (Wong *et al*. 2011: 746).

3.13.2 Exhaust flow and cooking process

According to the Foodservice Consultants Society International (FCSI 2006: 2), the appropriate exhaust rate from cooking process depends on several factors such as the menu, the type and use of the cooking equipment under the extractor hood, the style and geometry of the extractor hood itself and, how the makeup air is introduced into the kitchen. Relevant cooking appliances are categorised in Table 3.2. When cooking, the fumes rise, they are disorderly and diverse cooking methods have different surge characteristics (Timerbaeva 2010: 33).

Keil *et al.* (2004: 25) find that 39 % of the hoods met the flow rate guideline of the American Conference of Governmental Industrial Hygienists (ACGIH 2006), but a lower 24 % complied with the ASHRAE standard. Extractors for heavy-duty cooking such as char-broilers and woks had a low compliance rate of 18 %. Bhatia (2012: 18) posits that ovens and pressure fryers may have very little plume until they are opened to remove the food product. The author adds that open flame equipment exhibit strong, steady plumes (Southern California Edison 2004:1). The company adds that as the plume rises and captured by the hood, it is removed by the suction of the exhaust fan. A detailed investigation of thermal plumes is beyond the scope of this research. The presence of gas-fired griddles and open-top ranges do, however, need consideration of thermal plumes to evaluate IEQ for the design of restaurant kitchens in Durban in respect of ventilation comfort.

According to Shah (2013: 1), tandoor ovens, fashioned from clay common in kitchens serving authentic Indian cuisine, can reach temperatures of 480° C. There seems to be a widespread preference for tandoori dishes in Durban, the tandoor oven generates heat over 700° F (371° C) which contributes a unique flavour and texture in foods. A temperature gradient according to the author in a fully heated tandoor ranges from 588.5° F (309° C) at the bottom to 722.5° F (383.61° C) at the top of the cylindrical oven. Also, the repeated daily use of Teppanyaki in proximity to the oil sustained flames on a tabletop cook surface, can predispose the chef and staff to a lipid inhalation injury-causing exogenous lipoid pneumonia (Rahaghi *et al.* 2016: 4).

3.13.3 Air displacement

Vijaykumar (2017: 2) endorses the displacement of the volume of air as the first step in designing the ventilation system. For human comfort indoors, the ASHRAE 62.1 (2016) standard recommends nominally 0.0025 – 0.005 m^3/s (5-10 CFM) per occupant for various types of living spaces and human activity in it. These measures are important criteria for maintaining IAQ in commercial kitchens. Depending on the size of the space, this usually works out to 5-10 air changes/hour. This is supported by SANS 10400-O (2017: 17) which confirms it to be 10 air changes/hour and 17.5 L/s per person for commercial kitchens. The International Mechanical Code (IMC 2012) Section 403.3 requires 7.5 cfm/person (3.5 L/s) plus 0.18 cfm/ft^2 (0.08 L s/m^2) of the occupied space. A detailed investigation of extract flow is beyond the scope of this research. The results of Yi *et al*. (2016: 189) indicate that heat and gas capture efficiencies would increase as the ceiling exhaust outflow rate increases.

3.14 Hoods and canopies

Hoods and canopies ensure functional and energy-efficient ventilation of catering areas (Kong and Zhang 2016: 866). Park (2018: 4) states that the main purpose of a kitchen canopy is to extract excess heat, steam, fats, smoke and odour arising from cooking processes. Removal of these by-products of kitchen activity helps to achieve a reasonably comfortable and safe working environment, and prevents the spread of odours to other parts of the building. Consistent with Bhatia (2012: 18) the study will propose that at source removal of hot vapours should help prevent the kitchen from becoming too hot. This section will review multiple types of hood systems commonly mounted in commercial buildings to remove the effluent from cooking appliances.

3.14.1.1 Hood dimensions

The inside lower edge of canopy-type Type I and II commercial hoods have an overhang or extend a horizontal distance of not less than 6″ (15.2 cm) beyond the edge of the top horizontal surface of the appliance on all open sides (Park 2018: 4). The vertical distance between the front lower lip of the hood and such surface should not exceed 4′ (121.9 cm) (IMC 2015). However, Clark (2012: 54) argues that the front overhang should be a minimum of 9″ (22.9 cm) and the side overhang should be a minimum of 6″. When hoods serve on convection ovens, the overhang should be 6″ (15.2 cm) past the door opening at 90° from the oven. This often translates to an 18″ (45.7 cm) front overhang. The grilling and broiler units should not be at the end of the hood. These high heat and smoke-producing devices should be toward the centre of the hood’s length (Clark 2012: 54). Kitchens installing additional equipment as an afterthought can have appliances extending beyond the hood range. The capture area of range hoods should cover most of the range surface.

Notwithstanding, McNulty (2020: 1) recommends the hood be extended 3″ (7.5 cm) beyond the left and right edges of the cooktop.

3.14.2 Shape and angle of hood

The cross profile of American or European style cooking hoods is usually rectangular (Han *et al*. 2019: 7). The traditional Chinese style of cooking hoods is different, the front lower edge of the hood is designed at a 30 ° angle, but this reduces the volume of exhaust hood (Han *et al*. 2019: 7). Jeong *et al*. (2016: 124) states that in the case of the canopy hood, which is one of the existing local exhaust ventilation systems (LEV), a partial amount of effluent seeps out and accumulates on the upper workspace when the rate of ventilation is insufficient or when the buoyancy effect of the effluent is significant.

3.14.3 Burners

Livchak *et al.* (2005: 748) verified that a commercial kitchen is often characterised by high heat loads and air change rates. Kitchen workers can partially compensate for a low flow-rate exhaust fan by continuing to run the fan after cooking (Dobbin *et al.* 2018: 286). Rim *et al*. (2012: 3) show that range hood flow rate and burner position (front vs rear) can have strong effects on the reduction of indoor levels of ultrafine particles (UFP) released from the stove and oven, subsequently reducing occupant exposure to UFP. Higher range hood flow rates are generally more effective for UFP reduction, though the reduction varies with particle diameter. Dobbin *et al.* (2018: 288) suggest the use of a kitchen exhaust fan after the cooking process to reduce UFP levels near the gas stove. Sjaastad (2010: 53) recommends letting the kitchen exhaust hood run for 30 minutes after frying process, it led to a significant reduction in the level of particles in a much shorter time than when the extractor was turned off immediately after frying had finished.

The influence of the range hood exhaust is larger for the back burner than for the front burner (Rim *et al*. 2012: 16). Reduction for the front burner recorded between 31 % to 94 %. It seems that the use of back burner favours extraction with 54 % to 98 % and from 39 % to 96 % for the oven. While a detailed study of extraction rates is not within the scope of this study, it is useful in understanding what is needed in designing commercial kitchens.

3.14.4 Design of hoods

In addition to the amount of exhaust air factor, hood style, structural features and installation alignments, makeup air inlet, as well as the arrangement of equipment below the hood strongly impact on the capacity of the hood to capture and inhibit the spread of emissions (Han *et al*. 2019: 5**)**. However, attributes such as end panels, appliance location, overhang, space behind cooking equipment and size of the hood attributes are frequently ignored within the commercial kitchen ventilation (CKV) design specifications (Fisher *et al*. 2015: 26).

3.14.4.1 Type of hoods

The following type of listed hoods: wall-mounted canopy hoods, island canopy hoods either single or double and proximity hoods such as back-shelf, pass-over, or eyebrow have different capture areas and are mounted at different heights and horizontal positions relative to the cooking equipment (Fisher *et al*. 2015: 26). According to Han *et al*. (2019: 7), wall-mounted exhaust canopies require lower air velocities to exhaust thermal plume. The performance of different styles of exhaust hoods varies significantly.

To meet the required capture and containment, a single-island canopy hood requires a greater exhaust airflow rate than a wall-mounted hood, and a wall-mounted hood requires a greater exhaust airflow rate than an engineered proximity hood (California Energy Commission 2003: 10). Back shelf or pass-over are not allowed for extra-heavy-duty loads, and eyebrow hoods are not permitted for solid fuel and gas equipment or extra-heavy equipment and heavy-duty equipment, but suitable for medium and light-duty equipment (IMC 2015: 58).

3.14.4.2 Overhang

A large overhang also is appropriate for appliances that create thermal plume once doors or lids are opened (Fisher *et al*. 2015: 32). Stipulating a deeper hood such as 1.5 m vs 1.2 m will directly increase overhang, provided appliances are positioned as far back as possible in the hood (Han *et al*. 2019: 8). Increased overhang and a reduced rear gap of appliances improve the hood performance (Fisher *et al*. 2015: 34). Hood must overhang or extend a horizontal distance of at least 6″ (15.2 cm) beyond the outer edge of the cooking surfaces on all open sides. Additional overhang 10″ to 12″ (25.4 cm to 30.5 cm) can help improve capture effectiveness for open flame equipment such as char-broilers. An integral 3 inch (7.62 cm) air space between the back of the hood, and the wall should be provided to meet NFPA 96 clearance requirements against limited combustible walls (Bhatia 2012: 9).

3.14.4.3 Height and size

The width of the plenum and hood mounting height should be considered when determining the supply air to the unit (Clark 2012: 56). Sjaastad and Svendsen (2010: 267) verified that the varying heights could have a greater influence on the individual exposure of a chef, as the mass concentration of chemicals in the inhaling zone of the cook was greater when the distance between hood and stove was 50 cm than when it was 60 cm. The authors added that if the extractors were not able to remove all the thermal plume and food preparation smoke, some of the effluents would escape to the edges of the hood. However, Bhatia (2012: 9) claims that higher hood height improves capture efficiency. The depth of the hood should be a minimum of 24″ (60.96 cm) and should not exceed 36″ (91.44 cm). Moreover, Han *et al*. (2019: 8) claim that a deeper hood of 1.5 m increases the overhang and decreases the rear gap, thus improving the ability to capture and contain the thermal plume. A larger exhaust hood depth has a greater impact on hood performance than that of the reservoir volume when the hood ceiling is lowered (Han *et al*. 2019: 8).

According to Fisher (2015: 34), a deeper hood enables a larger overhang and accompanying decrease in exhaust airflow for capture and containment. This reduction in exhaust rate is attributed to the increased hood tank; increasing capture chamber volume will increase the interior hood height. This is not applicable universally, as the ceiling height of kitchens is set. A proximity hood can outperform a canopy hood. A mounting height of 3.5 feet (1.1 m) is unreasonable for a canopy hood; low exhaust is required to restrict the cooking emission (Fisher *et al*. 2015: 34). However, Halton (2007: 43) claims that the installation height of the hood should be 1.1 m above the appliances or 2 m above the floor. Undersized range hoods inevitably lead to positive pressure, which manifests itself into smoke and effluent from cooking remaining in the kitchen, making it both a hot and uncomfortable working environment (McGowan 2009: 3).

3.14.4.4 Efficiency and flow rates

Zhao *et al.* (2013: 139) analysed Chinese style kitchen hoods and found that increasing hood volume did not improve capture performance. However, side panels did improve the capture efficiency, especially at higher positions. In addition, when the exhaust opening was located at the rear of the hood, the hood capture efficiency improvement was enhanced. The results of the flow pattern in a commercial kitchen hood system show that the highest velocity of plumes has more tendencies to flow past the lower part of the filter (Pairan 2017: 5). From the simulation work, the velocity of airflow tested is 0.28 m/s; enough to control the heat and give enough comfort to the working space for the size of the kitchen simulated (Manshoor *et al*. 2014a: 1). Sound application of the makeup air in the kitchen hood can advance IAQ in a commercial kitchen and keep the kitchen areas comfortable to the workers. The study of makeup air is beyond the scope of this research and will not be discussed further.

The net exhaust volumes for hoods can be reduced during part-load or no cooking conditions. National Fire Protection Act 96 (NFPA) USA and Canada permit the exhaust duct velocity to reduce to a minimum of 500 fpm (2.54 m/s). It is also important to reduce the makeup air parallel with the exhaust rate to keep the facility pressure relationships constant (Clark 2012: 56). Allen (2014: 2) reports that inadequate makeup air can cause a negative pressure condition in a building.

However, drawbacks are seen in areas that are drafty or stuffy, doors that slam, poor air quality, reduced energy efficiency, and back-venting of combustion gases from HVAC equipment.

The air velocity for Type I ducts should not be < 500 fpm (2.54 m/s) for variable flow and reuse of existing ducts and should not be > 2,500 fpm (12.7 m/s) for reasonable noise levels. Variable speed controls regulate the net exhaust volume for hoods. Moreover, duct hood exhaust collars are sized to provide a velocity of 1.800 fpm (9.1 m/s). Measures of airspeeds in different areas of a kitchen will influence thermal comfort and help determine the criteria for the design of restaurant kitchens.

3.14.4.5 Hood maintenance

Food service establishments should clean exhaust hoods regularly and display a certificate. Routine hood cleaning, as outlined by NFPA-96 guidelines, will keep hood, baffle filters, grease ducts, fans and grease tray areas free from dangerous grease build-up preventing fire hazards in kitchens (National Fire Co. 2020: 1). The NFPA is the governing body providing the minimum codes of standards for the kitchen exhaust cleaning industry via the NFPA 96: Standard for Ventilation Control and Fire Protection of Commercial Cooking Operations. Hood Products (2020: 4) proposes a schedule of inspection for grease build up in Table 3.3.

Table 3.3 Annual cleaning schedule of extractor systems

Type or Volume of Cooking Frequency	Frequency
Systems serving solid fuel cooking operations	Monthly
Systems serving high-volume cooking operations such as 24-hour cooking, charbroiling, or wok cooking	Quarterly
Systems serving moderate-volume cooking operations	Semi annually
Systems serving low-volume cooking operations, senior centres.	Annually

In order to ensure that the exhaust system is not at risk for a grease fire, the kitchen hood exhaust system should be cleaned according to fire code standards regularly (Bare Metal Standard 2020: 2). The exhaust system must be consistently inspected and cleaned to remain compliant with the health department and fire inspectors. Further to Table 3.3, the amount of cleaning required depends on how busy the kitchen is. Also, Burt (2017: 1) adds cleaning interventions for:

- Average restaurants – 90 day cleaning requirement;
- Fast-food restaurants – 30 day cleaning requirement;
- Oven hoods – 180 day cleaning requirement; and
- Hoods over non-greasy appliances – 1 year cleaning requirement.

3.14.5 Filter selection

Grease filters in a hood are designed to remove grease particles from the exhaust air stream (Bhatia 2012: 22). On the other hand, Clark (2012: 55) emphasises the primary purpose of a filter is to prevent cooking flames below from entering the exhaust duct. The quantity of exhaust air keeps the filter's surface temperature at 93 °C. The configuration of the filter's baffle is to facilitate condensing of the moisture and grease vapours to be captured by centrifugal separation as they pass through the turns and cooling surfaces. Bhatia (2012: 22) reports that exhaust systems with broken, missing and undersized filters prone to collect accumulations of highly combustible grease deposits throughout the entire duct system can cause a flash fire.

Grease filters are baffle filters and multi-cyclic filters are easy to clean without any obstruction. This is to avoid the increase of pressure drops across the filter and the decrease of exhaust airflow, which will affect the system efficiency (Pairan 2017: 33). Baffle filters are commonly observable in Durban kitchens**.** The baffle plate increases the capture velocity by reducing the opening area of the hood; therefore, the ability to capture the contaminant from the thermal plume can improve (Han *et al.* 2019: 8) and **(**Kotani *et al*. 2009: 1).

Basic hood grease filters also include an extractor cartridge and an extended surface filter (Clark 2009: 21). The filter type designated should match the estimated performance of a hood. Simple baffle filters can be installed in light and medium-duty hoods as per IMC (2015) and NPFA-96 regulation**s**. The extractor filters that have a greater baffle length path are suitable for heavy and extra heavy hoods as it permits for additional condensing of the vapours before being centrifugally separated (Clark 2012: 56).

Thomas (2014: 1) adds that Ultraviolet technology (UV) can be applied to improve IAQ for HVAC systems that kill mould and bacteria in HVAC systems. UV technologies in air cleaning systems include a UV oxidation process that has a disinfection effect to kill bacteria (Alexandrova 2009: 26). UV technology appears to be unknown in commercial kitchens in Durban.

Electrostatic precipitators are highly efficient filtration devices that minimally impede the flow of gases through the device and suitable for high volume high grease catering establishments (Airclean 2018: 1). Clark (2009: 22) recommends that static precipitators should not be used to control the stack effluents until all the basic options have been exhausted, such as utilising a longer baffle path or extended surface filter.

3.15 Relative humidity

Zhang and de Dear (2019: 9) claim that high humidity exacerbates warm sensations in high temperatures and cold sensations in low temperatures. Within a comfortable temperature range, people can tolerate a large range of humidity levels. However, in warmer seasons, occupants' thermal sensations and humidity may be positively correlated or not correlated depending on the indoor temperatures. As the humidity in the air increases, sweat does not evaporate readily and stops entirely when at 90 % RH (Ghasemkhani and Naseri 2008: 60). According to Lan *et al.* (2008: 471), females are more sensitive to temperature and less sensitive to humidity than males.

RH plays a large part in conjunction with temperature to influence discomfort. In EN ISO 7730 a humidity range of 30-70 % RH is recommended, but mainly for IAQ reasons (Boduch and Fincher 2009: 2). High levels of RH can work against the evaporative cooling effects of sweating and leave the body prone to overheating (hyperthermia). The authors add that human beings are sensitive to slight temperature changes yet cannot perceive differences in RH levels. Hence, Sateri and Finnish Society of Indoor Air Quality and Climate (2004: 12) find less attention to humidity in the comfort range of temperatures as it has a minor impact on the thermal sensations of the human body. Also, the influence of humidity on the preferred ambient temperature in the comfort range is relatively small according to EN ISO 7730 (2005) and ASHRAE 55 (2017).

According to Faizal *et al*. (2011: 13), human thermal sensations react naturally toward the air temperature, to maintain thermal comfort within an indoor RH of 30 % to 60 %. The authors add that a low RH causes dryness and itching whereas a high RH leads to an increase in skin temperature, residual skin dampness and encourages fungi. Humidity is a comfort indicator in sub-tropical Durban. To keep the RH at a comfortable level, a determining supply of dry air is needed. With thermal displacement ventilation, it is possible to reach the same indoor target with relatively higher humidity in the air supply (Kosonen 2010: 3).

Also, the RH in different kitchen zones tends to vary. Simone *et al*. (2013:1007) reveal that the highest RH (76 %) was in the dishwashing area. Similar high humidity levels were recorded in food-preparation and cooking areas with spot measurements. Li *et al*. (2012), however, reported very high indoor temperature during cooking and low RH that made the chef feel very uncomfortable in a Chinese kitchen. For optimum occupant comfort, RH of 40 % to 60 % is recommended (Mustafa 2017: 13) and (Passive Design 2018: 3).

In another line of enquiry, Rosone (2016: 1) theorises that poor humidity control is not only a discomfort issue for restaurant kitchens but results in condensation including mould and mildew growth. Moisture extraction through HVAC and provision for natural ventilation in commercial kitchens usually observed helps to reduce humidity. According to Environmental Protection Agency (2017: 3) 60 % RH levels are enough to encourage mould growth; humidity levels less than 60 % provide an ideal environment in the kitchen. McGowan (2009: 3) informs that as per Queensland Government Department of Industrial Relations fact sheet (u.d) on heat stress in the café and restaurant industry, an ideal working environment should have a temperature range of 20° C to 26° C and RH between 40 % and 70 %.

A study of restaurant kitchens in Tehran by Ghasemkhani and Naseri, (2008: 63) reports that at an RH below 30 % dry air affected eyes, skin and the mucous membrane whilst RH above 60 % supported the growth of pathogens or allergens. Additionally, high humidity causes vent diffusers to drip water on the floor and form droplets on glass entrances and openings. Floors that stay damp or need a lengthy period to dry, further raise the humidity. Hence, the high quantity of water vapour produced is not a direct health concern but can contribute to high indoor humidity and related mould and pest issues (Kim *et al.* 2018: 1). Notable**,** Munters (2004: 2) finds that when staff become too hot and want to turn the thermostat down, RH is increased.

3.16 Conclusion

This chapter commenced by discussing natural, artificial and mechanical ventilation, as well as architectural features of the building that affect ventilation. It then proceeded to deliberate on how IAQ is affected by pollution due to the cooking process. It proceeded to a debate of factors affecting exhaust flow and how to prevent inadequate ventilation. The next chapter will discuss the effect of noise on IEQ of kitchens.

CHAPTER FOUR

NOISE AND ITS EFFECT ON WORKERS' HEALTH

4.1 Introduction

The previous chapter discussed the factors that influence thermal comfort in kitchens due to ventilation. This chapter will discuss how noise penetrates the workplace and creates a disturbance that increases the risk of hearing impairment, and the strategies to prevent hearing loss.

At a basic level, noise may be defined as any unwanted sound (Nassiri *et al*. 2013: 87). The City of Tshwane, Noise Management Policy (2004: 2), adds that noise nuisance in the Noise Regulations is any sound which disturbs the convenience or peace of any person. In terms of the Environment Conservation Act (73 of 1989) and the Noise Control Regulations in South Africa; 'to prove that a Noise Nuisance exists, a rational person must find a particular noise unbearable or acutely affecting the enjoyment of their property' (Hatchuel 2018: 1).

4.2 Noise in Durban

Consistent with other municipalities, constraints on the behaviour of Durban residents are enforced by gazetted bylaw, 'Nuisances and Behaviour in Public Places', implemented in 2011 (eThekwini Municipality 2015). Yelling, shrieking, earsplitting noise or deafening noise is forbidden by local legislation. This does not include an emergency or rescue announcement as per Konig in South Coast Sun (2019: 2).

Currently, no assessment on noise research in Durban restaurant kitchens have been conducted, so essential to correlate with occupational health control measures. Unsurprisingly, therefore, Gladieux (2015: 1) establishes cause for concern as little data exists regarding noise in the restaurant industry. Although numerous food service workers toil in noisy environments, not much is known about the acceptable level of noise in kitchens and the effect of noise exposures on workers.

4.3 Noise in commercial kitchens

Lao's *et al.* (2013: 5) comparative studies on occupational noise exposure and noise induced hearing loss (NIHL) among Chinese restaurant employees and entertainment workers report an average noise level of 86.9 decibels (dBA) while cooking. Wok cooking occurs at high temperatures by using high pressure gas stoves that generated a higher noise level. Such pressure gas stoves seem to be a common feature among Indian, Chinese and Thai kitchens in Durban. Alonso and O'Neill (2010: 256) reported that sounds of small equipment such as rattling pots and pans in open kitchens created loud noise. Even equipment as small as a spoon, when dropped on a plate produces 110-115 dBA (Teder 2019: 1). Equipment such as air-conditioners, fans, food blenders and coffee grinders have noise rating indications and they produce lower noise levels compared to other equipment commonly used in most food service establishments (Engineering ToolBox 2004: 1). Fischer *et al*. (2014: 2) report that noise levels of different blenders varied from 82 dBA to 91 dBA, hand mixers 77 to 86 dBA, electrical coffee grinders 71 to 83 dBA, espresso machines 61 to 71 dBA, and extractors 54 to 68 dBA.

Drafts from fans and oven fans seem to interfere in normal communication in the kitchens (Figure 9.4). The National Academy of Sciences (2019: 1) claims that on a large fan with an open intake, the intake noise is dominant. While there might be a constant, it seems that noise in kitchens can vary before service and during service, depending on the food production system. Chef Services Group (2020: 1) states that cook-chill systems are used by food suppliers nationwide. Such a method of cooking in advance may help to reduce noise levels during rush hour in kitchens.

Moreover, Rusnock and Bush (2012: 109) add that noise from outside the restaurant such as traffic, other businesses and airport locations increase normal kitchen noise. The combined internal and external noise sources seem to have the potential to be uncomfortable, if not hazardous. Achutan's (2009: 145) study of a dietary department found that the noise level from the dishwashing machine was within tolerance. However, when combining the noise from the adjacent food preparation area from grinders, utensils and metal-to-metal contact between stainless steel pots and pans and metal racks, it increased the noise level above the NIOSH recommended exposure limits (REL). Jiang and Wang (2008: 1) established that noise pollution was higher during cooking than before cooking among restaurants of varying capacities. These ranged from 74 dBa to 79 dBA exceeding the environmental noise limit of the city.

Green and Anthony (2015: 489) similarly, affirm that the threat of hearing loss to millions of kitchen workers is unidentified. Kitchens are notoriously noisy, but they do not have to be (Serfozo 2018: 1). According to SANS 10103 (2008: 12-13), the maximum equivalent continuous rating level for ambient noise recommended in restaurants and cafeterias is 45 dBA and 55 dBA respectively; 55 dBA is recommended for hotel and hostel kitchens.

The causes of noise in kitchen include the following:

- Noise is created due to poor upkeep and improper functioning of equipment for example, parts of an equipment can become unfastened over time or become worn (Twin City Fan 2018: 28)and lack of lubrication at appropriate times (OSHA Technical Manual 2015: 71).

- Noise in equipment is caused by vibration as in the case of fans, grinders, air-conditioners and refrigerators. Fans mounted on supports have a natural vibration frequency, the structure will tend to continue to vibrate once it has been set in motion.
- Mechanical vibration pertains to rotating parts, fasteners and structural supports.
- Duct attachment to the support structure may be loose; for example, a fan not supported could be the cause of extractors making a loud noise in kitchens (Fischer *et al.* 2014: 1).

4.4 Noise types

Vardaxis *et al*. (2018: 166) envisages low-frequency noise (LFN) as a long wavelength, and 45 Hz from the humming of a refrigerator. LFN is broadband noise with a low frequency (10–250 Hz). Other environmental LFN include ventilation systems, pumps, compressors, diesel engines, as well as indoor network installations. Sound with low-frequency characteristics can be more distressing when transmitted through light-weight building material

In addition to LFN, other types of noise include continuous, intermittent and fluctuating. Continuous noise is produced by machinery that continuously runs without interruption from factory machines, air-conditions and extractors. Intermittent or variable noise rises and declines swiftly such as workshop machines that functions in rotations. Impulsive noise is usually found in the building and demolition industry where there is unexpected high noise pulses (Noise News 2015: 1).

4.5 Adverse health effects of noise

Occupational hearing loss resulting from workplace noise causes health hazards and is a slow and progressive condition. Akbari *et al.* (2013: 2**)** ratify that exposure to noise at work causes deafness and the progression to NIHL and depends on factors such as frequency, intensity and duration of noise exposure (Sayapathi *et al.* 2013: 3). Welch *et al.* (2013: 224) confirm the link between environmental noise and health problems.

Blackwell *et al*. (2014: 40-41) report that NIHL is the third most widespread chronic health condition in the US. The potential health effects of noise pollution are said to be numerous, pervasive, persistent, and medically and socially significant (Goines and Hagler 2007: 287). Noise impedes the learning process, psychological development, social activity and verbal communication, and impairs job performance and safety in the workplace (City of Tshwane, Noise Management Policy 2004: 2).

As reinforced by several authors such as Goines and Hagler (2007: 287), Daniel (2007: 229) and Nassiri *et al*. (2013: 87), noise pollution disrupts the balance of human life and affect health, directly and indirectly. Kerns *et al*. (2018: 477) confirm that along with hearing impairment, noise exposure is associated with many illnesses. World Health Organization (WHO 2015: 1) accordingly reveal that noise sensitivity is related to poor health outcomes and loss of well-being (Graydon *et al.* 2018: 23). Hence, strategies for creating quieter kitchens will increase kitchen staff productivity and reduce accidents (Serfozo 2018:1).

4.5.1 Personal factors

Although age is commonly associated with hearing loss, genetics and gender are also linked. Daniel (2007: 229) claims that non-modifiable risk factors related to noise-related hearing loss include increasing age, genetics, male gender and race. The author also adds that modifiable risk factors are voluntary exposure to loud noise, non-use of hearing protection, smoking, lack of exercise, poor diet, tooth loss and the presence of diabetes and cardiovascular disease.

Amongst others, noise interferes with concentration and communication, with corresponding economic and intangible losses (Daniel 2007: 229). Serious effects of environmental noise amongst others include general annoyance, sleep disturbance, or reduction in quality of life, but it also contributes to a higher prevalence of hypertension and cardiovascular diseases (Munzel *et al*. 2014: 835).

Several extra-auditory effects of noise are shown to be psycho-physiological. Zare *et al.* (2019: 112) found that during the night shift, sound pressure level (SPL) and exposure time significantly increases cortisol concentrations, a hormone used as a biomarker to study the effect of noise-induced stress. Prashanth and Sridhar (2008: 90) and Singh *et al.* (2010: 37) claim that higher noise levels result in irritability and outbreak of psychological distress amongst industrial workers, heart disease, absence due to work illness and tiredness, respectively. Credence to the findings is afforded in the City of Tshwane, Noise Management Policy (2004: 7); a correlation was found to exist between high exposure to noise and increased admissions to mental hospitals.

4.5.2 Social and behavioural effects

Goines and Hagler (2007: 291) posit that social and behavioural effects of noise exposure are multifaceted, understated and unintended. These effects comprise deviations in everyday behaviour such as closing windows and doors to eradicate outside noises; evading the use of balconies, patios and yards; and increasing the volume of radios and television sets. The authors observe that the change in social behaviour range from hostility, aloofness, disengagement and contributing to accident and depression.

Noise pollution seems to have a significant impact on psychological health and well-being. Picard *et al.* (2008: 1644) found an association between accident risk and worker's hearing sensitivity in a longitudinal study in Quebec. Dzhambov and Dimitrova (2014: 95) also underlined the impact of noise on displaced aggression (DA) in different subgroups of residents due to their relatively lower socio-economic standard and quality of life in Bulgaria. Loud noises, higher noise sensitivity and continuous noises were associated with higher levels of DA. Therefore, the social climate might modify the way people perceive and react to environmental noise.

Low-frequency infrasound at high decibells can cause tremors inside human organs and it is painful (Cone 2017: 5). Greater annoyance was perceived when vibrations that comprise of low-frequency components accompany noise. Pawlaczyk-Luszczyk *et al*. (2015: 185) found that exposure to low-frequency noise (LFN) can influence human mental performance and at moderate levels adversely affect visual functions, concentration, and attention among subjects in Poland.

4.6 Acoustic comfort

Locally, the Green Building Council South Africa (GBCSA) leads the transformation of the SA property industry to ensure that buildings are designed, built and operated in an environmentally sustainable way (Property24 2014:1). Leadership in Energy and Environmental Design (LEED) is a standard green building guideline that includes acoustic credits, but it is not a mandatory element as yet. On the other hand, the guideline, Global Sustainability Assessment System (GSAS) does incorporate acoustics. Notwithstanding, the impact of acoustics on occupant comfort and productivity whilst established in the literature (Shafaghat *et al.* 2014 cited in Al-Horr *et al.* 2016: 7), its place in the concept of green buildings is not widespread. For instance, Lee's (2019: 571) assessment of the performance of IEQ in LEED-certified homes found the acoustic quality to be a low priority. Moreover, the inclusion of acoustic comfort according to Schiavon and Altomonte (2014: 114) into green building guidelines is a low priority.

Frontczak and Wargocki (2011: 925) posits that acoustic comfort is "a state of contentment with acoustic conditions". Rindel (2002: 152 cited in Vardaxis *et al*. 2018: 152) adds that acoustic comfort is a concept that can be characterised by absence of unwanted sound and provides opportunities for acoustic activities without annoying other people. Al-Horr *et al*. (2016: 6) state that the acoustic comfort of buildings is the capacity to protect occupants from noise. Hence, the provision of a good acoustic environment is mainly associated with preventing the occurrence of annoyance. Of relevance to the commercial kitchen is Mujeebu's (2019: 3) claim that the acoustic comfort can be affected by factors such as the geometry and volume of a space, generation of sound within or outside the space, airborne noise transmission, impact noise, and the acoustic characteristics such as absorption, transmission, and reflection of sound of the interior surfaces. Schiavon and Altomonte (2014: 148) lament that despite existing knowledge in this area, acoustic comfort is still lacking.

Managing acoustic comfort consists of minimising intruding noise and maintaining satisfaction among occupants (Saint-Gobain 2010: 1). In a related line of enquiry, Frontczak and Wargocki (2011: 937) suggest that acoustic comfort is affected by the country of origin.

There is a direct relationship between acoustic comfort and occupant productivity in commercial buildings (Al-Horr *et al*. 2016: 6). Acoustic problems arise from airborne sounds, outdoor noise, noise from adjacent spaces, noise from workplace appliances and sound of nearby facilities (ANSI/ASHRAE Standard 55 2010: 2). André *et al*. (2020: 990) confirmed that the noise produced by the fan was an obstacle to increasing airflow. Acoustic problems, therefore, need to be anticipated and addressed at the design stages of the building (Bluyssen *et al.* 2011: 2632). Despite being recognised as an important parameter, Andersen *et al*. (2009: 11) indicate that acoustic comfort is not considered a high priority in building design leading to post-occupancy productivity-related issues.

4.7 Noise and productivity

Noise affects human health and attentiveness as well as increases fatigue and absenteeism from work and therefore necessitates increased relaxing time during work (Akbari *et al.* 2013: 1 and Nassiri *et al*. 2013: 88). These indicators according to Naravane (2009: 27) result in serious consequences on the performance and productivity of workers, with mental health effects. Goldsmith (2013: 9) mentions that the workplace studies have established that noise in the workplace lowers productivity by two thirds. Mohammadizadeh *et al*. (2015: 208) and (NIOSH 2015: 1) report that noise corruption impact on the hearing of workers and affect worker productivity; optimal noise management seems to result in better productivity. It is therefore clear that unavoidable noise and bustle in a commercial kitchen requires careful layout and efficiency of kitchen operations as preventative measures.

4.8 Demographics

Age and gender seem to have an effect on sensitivity to hearing.

4.8.1 Age

Although age is associated with hearing loss, there is no known singular cause. Loss is caused by changes in the inner ear that occurs as one grows older (Medlineplus 2019: 2). Daniel (2007: 226) claims that NIHL is common mostly amongst people above the age of 65, while hearing loss amongst children and young adults is increasing. Dzhambov and Dimitrova (2014: 95) confirm that younger ages are positively correlated with noise sensitivity and aggression. Noise seems to be more of a problem for the 25 to 39 year age cohort (European Agency for Safety and Health at

Work 2017: 34). Yamasoba *et al*. (2013: 30) list risk factors for age-related hearing loss (AHL) in humans from epidemiological studies.

4.8.2 Gender

Nyilo and Putri (2019**:** 88) reported that Indonesian hospital workers with NIHL were mostly kitchen workers (68.75 %) comprising of females (58.33 %). Lao *et al.* (2013: 7) claims that being male and elderly was notably related with an increased risk of hearing loss in both food service and entertainment industry. Tiller *et al.* (2010: 534) reported that there were differences in the way males and females experienced acoustic environments as females were more sensitive to sound. The EASHW (2017: 7) find that noise exposure was higher than average in hotels and restaurants. A quarter of the time exposure to noise was reported by 38 % of men and 30 % of women. Among women, the moderate or worse hearing difficulty was common among caterers and cleaners. However, Nelson *et al*. (2005: 446) reported that the worldwide morbidity of occupational NIHL was 16 % in 2000; the effects of the exposure to work-related noise are predominant in men than women in sampled sub-regions. Yang and Moon (2019: 628) find that women had higher scores for acoustic comfort with at 55 dBA than those of men with statistical significance.

4.8.3 Ethnic groups

Fligor *et al*. (2014: 1535) reported from a survey on noise that 40 % of Africans did not exceed the daily and weekly allowance for noise compared compared to 14 % of African Americans who did not exceed the daily and weekly allowance. Casey *et al*. (2017: 7) found evidence of cultural and social status differences in noise exposure in the US. Lin *et al*. (2011: 109) report that public health reports of hearing impairment have confirmed that the likelihood of hearing disorder is considerably minor in Blacks than in White persons. A darker-skinned individual has higher inner ear melanin offers protection from hearing disorder. Yamasoba *et al.* (2013: 30) found that due to the genetic disinclination of the African race, there was a 60 % to 70 % lower odds of NIHL and AHL amongst them compared to white subjects.

According to Crandell *et al*. (2004: 184), African-Americans were less likely than Caucasians to identify symptoms of excessive noise; the former are at risk of hearing damage with the latter being less likely to participate in activities that are potentially hazardous to hearing. This difference, among African-Americans, might due to the absence of connection between hearing-protection information to self-perceptions, goals, or activities. This observation may be pertinent in the context of the proportionally high African staff in South African commercial kitchens.

4.9 Acoustics classification

At an elementary level, building noise may range from being unbearable to being quiet. According to Rasmussen (2014: 1), acoustic classification schemes for acoustic conditions in commercial kitchens do not seem to be available, although invaluable for quality of work-life among food service workers. Nonetheless, Goyal (2010: 2) has provided classification of building noise, however, not valid for kitchens. Farber and Wangs' (2017: 6) report on the sound levels of restaurants and their impact on health and hearing advise that classified sound level thresholds are guided by Hearing Health Safety Standards in Table 4.1. Moderate and loud categories of noise affect the ability to hear and converse with others.

Table 4.1 Noise classification in restaurants

Noise levels	Category
70 dBA or lower	Quiet
Between 71 – 75 dBA	Moderate
Between 76 and 80 dBA	Loud
81 dBA or higher	Very Loud

Fligor *et al*. (2014: 1535) cites the class descriptions for acoustic comfort in residential units, suitable for office environments that are much quieter when compared to a busy commercial kitchen. It seems unrealistic to expect noise levels lower than 70 dBA in a busy kitchen in cooking areas. An evaluation of noise levels in kitchens will indicate amongst others the need for sound absorption fittings and improved maintenance schedule for mechanical equipment.

4.10 Occupational risk from noise

NIHL, due to occupational exposure, represents nearly one-third of all occupational diseases in Europe irrespective of the economic sectors (Arezes *et al*. 2012: 171). According to Starkey Hearing (2017: 1), deafness is a protracted illness in the USA subject to loud noise. Simone *et al.* (2012: 5) report from a survey of 100 kitchens in the USA that noise in the kitchen environment was distracting.

4.10.1 Noise-induced hearing loss (NIHL)

Green and Anthony (2015: 9) examined predisposing elements associated with noise exposures amongst food service workers and that interventions be undertaken to prevent NIHL. It seems that cooking operations can lead to loud noises from pounding meat to blenders and grinders as well as loud workers. Whilst there is no noise-induced hearing loss in commercial kitchens, NIOSH (2015: 1) reports that any worker can be at risk for noise-induced hearing loss in the workplace.

Whilst compliance with occupational regulations in some sectors can assist management, it seems that there is no regulation on acceptable noise levels in commercial kitchens, as is the case for mines. According to Edwards *et al*. (2011: 2), 73.2 % of miners in South African are exposed to noise levels above the legislated occupational exposure limit of 85 dBA. NIOSH (2015: 133) explains that 90 % of coal miners and 49 % of miners have NIHL by the age of 50 years. This may be attributable to a lack of compliance.

Hearing protection devices (HPD) and smoking (Jaruchinda *et al.* 2005: 232) and alcohol consumption (Yamasoba *et al.* 2013: 32) all have a significant association with hearing loss. Alcoholics are associated with increased risk of hearing impairment. The effect of smoking on hearing loss is still controversial.

Although noise is not the subject of many empirical studies, it should be a concern in the hospitality industry, especially from the duration of exposure. Gardner *et al.* (2014: 191) state that staff in cafés may be at moderate risk with a daily noise exposure level of 74 dBA. A study of army kitchens in China revealed noise levels between 77.70 dBA and 83.50 dBA, which was higher than in dining room and storeroom areas and the tingle and tinnitus of ears in the kitchen worker group was higher than other staff (Yu *et al*. 2010: 1). The authors add that some cooking rooms had the highest noise levels affecting the hearing abilities of kitchen workers. Noise levels in different areas of a kitchen, therefore, influence acoustic comfort (Yu 2009: 45).

The next section will discuss the assessment of noise levels, prevention of NIHL, and strategies for noise reduction.

4.11 Assessment of noise levels

As a significant component of environmental criteria in the kitchen (Sanjog *et al.* 2013: 508; Akbari *et al.* 2013: 1), the measurement of noise is an important feature in the kitchen environment. Cagno *et al.* (2005: 297) and Arezes *et al.* (2012:172) accordingly, recommend measurement of the acoustic characteristics of the sources, duration of exposure, the type of equipment and procedure. The current study will observe the sources of noise and noise levels before and during cooking operations.

As with most measures, there is a need to eliminate subjectivity (Fernandez *et al.* 2009: 753). The use of measuring instruments reduces measurement uncertainty, and include the use of dosimeters, sound level meters, selection of measurement period and workers' observations (Arezes *et al.* 2012: 172). Also included are components in evaluating health effects (Prashanth and Sridhar

2008: 90). Measuring noise frequency is, however, outside the delimitations of the present research. Noise levels in different areas of a kitchen will influence acoustic comfort and help understand the nature of this essential criterion in the design of commercial kitchens in Durban.

4.12 Prevention of NIHL

Traditionally, prevention of NIHL was addressed by providing HPD and reducing noise emissions. The burden of NIHL could be diminished by engineering controls to reduce noise production at its source (Tikka *et al*. 2017**:** 7). However, for many occupations, this is insufficient, especially when noise levels exceed 130 dBs to 140 dBs (Lynch and Kil 2005: 1291). Effective management of noise at work is essential as workers are not timeously motivated to take any action because NIHL occurs gradually, is invisible and has an ambiguous time course in an individual (Gardner *et al.* 2014: 191).

Hansia and Dickinson (2010: 72) argue that in South African goldmines, NIHL may persist due to limited use of HPDs and suboptimal knowledge of noise as a hazard. Comparable results were found in India regarding ignorance among workers about the harmful effects of noise on hearing and health (Nandi and Dhatrak 2008: 53).

4.12.1 Strategies for noise prevention

Hearing loss and prevention programs should be targeted at occupations identified with high noise exposure and in those industries with the highest proportion of noise-exposed workers with non-use of HPDs (Tak *et al.* 2009: 358). Occupational and Safety Health (2019) specialists confront noise-related issues in the workplace with the grading of noise to regulate noise by elimination or substitution of noise sources, collective control measures through engineering and work organisation and personal protective equipment (PPE). OSHA controls intends to protect workers from the adverse effects of noise pollution environment (Goines and Hagler 2007: 287). The different techniques must be optimally balanced to avoid extreme behaviour amongst workers. If noise-masking does not reduce the noise sufficiently, occupants will speak louder than normal to be heard causing further annoyance amongst fellow workers.

Measures, such as audiometric monitoring of workers hearing to reduce noise pollution in the Chinese army benefitted staff. Arezes *et al*. (2012: 172) observed that due to the magnitude of the noise problem, the European Directive has set exposure limits for workers' protection according to their exposure profile (European Agency for Safety and Health at Work 2008: 34). Hearing protectors should be worn if the source of the noise cannot be enclosed or isolated. A per Chao and Henshaw (2002: 6-7), OSHA 3074 recommends the introduction of a hearing conservation programme (HCP) that contains audiometric testing and training. It seems that only manufacturing units have a hearing conservation program in Durban where all workers on the factory floor have to wear HPDs.

A noise contour map has become useful in managing noise and according to Boston Logan (2019: 1) a noise contour is a line on a map that symbolizes equal levels of noise exposure. Forouharmajd and Shabab (2015: 46) two measures can display the noise contour charts as emission profiles on a floor plan and include SPL and noise intensity. Noise contour maps, with workplace layouts, give important data on zones of low sound levels. The proposal by Banerjee *et al*. (2009: 325) that high-risk noise pollution areas determined by noise map has potential for kitchen noise management.

Sietsema (2008: 1) claims that the blame for all the noise comes from the clean, slick and modern look favoured by so many restaurant operators and their customers. The sound is reflected due to the restaurant's hard floors, bare tables, and from the high ceilings according to Zagat survey of restaurants in 2015. Glass reflects sound and a slap-back effect can occur when angles and surfaces bounced noise from one to the other. Noise absorbent panels according to Forouharmajd and Shabab (2015: 49) reduce noise.

Earlier, Loewen and Suedfeld (1992: 1) recommend the use of absorptive materials such as rubber to insulate buildings reduces heavy vibrations and disturbing sounds. According to OSHA (2014: 79), reflected sound that reverberates from the walls, ceiling and floor will add to the sound wave propagating directly from the source to the receiver and increases the overall noise level within a room. Acoustical absorptive materials installed on walls and ceiling reduce the reflected sound, absorb and dissipate sound before it can be reflected. Special acoustic tiles can also be fixed to the kitchen ceiling, but polystyrene is not permitted in commercial kitchens. Ceiling absorption is the most effective method to enhance the acoustic environment of a restaurant.

Other ways to reduce noise in the kitchen (Fischer *et al.* 2014: 1) include the following:

- Preventive maintenance includes properly lubricating and aligning moving parts and decreasing the speed of the equipment (OSHA Technical Manual 2014: 71).
- Extractor fans must be securely supported. It seems that this could be the cause of extractors making a loud noise in kitchens.
- Noise excitation reduction can be achieved by damping, decoupling and encapsulation, damping reduced noise emissions up to 3 dB.

With regard to kitchen activities, Achutan (2009: 145) recommends that non-stacking of dishes will reduce clanging noise, and hearing protectors for dishwashing room staff be adopted. Noise levels in kitchens generally range from 65-85 dBA.

4.12.2 Noise reduction design options in kitchens

Eliminating noise in kitchens is beneficial for workers as it creates a calm, pleasant atmosphere, making employees more alert and focused and providing better conditions for higher quality work. It enables communication, which not only raises efficiency but also improves safety when important messages need to be heard and understood (Ecophon 2010: 3).

Alpert (2018: 1) claims that designers can stratergise the exposed kitchen setting to reduce noise. Acoustic separations, floor treatments and perforated metal ceiling tiles are important but rarely enough to cut down on all the noise produced during a busy rush. Preparation work and clean-up can be separated from the chef's area or open cook lines.

Pay Less Kitchens (2014: 1) recommend that kitchen noise can be minimised by utilising the right layout and design for the kitchen**.** For instance, Zhang *et al*. (2015: 1) suggest that when intelligibility of dining hall is poor and the noise is mainly from the customers, a layout that shortens the distance between speaker and listener can improve speech intelligibility, as is possible in open-plan kitchens. Earlier, Yu (2009: 67) recommends redesigning the kitchen and dining areas to reduce noise spillover. The International Finance Corporation - EHS Guidelines of World Bank (2007: 1) add that several design possibilities exist to reduce noise. These include:

- Selecting equipment with lower sound power levels. Modern kitchen equipment has lower noise levels.
- Installing silencers for extractor fans. Clements *et al*. (2019: 3) observe that high flow rate ventilation system might provide good air quality but can also lead to increased noise levels due to fan and duct noise.
- Installing suitable mufflers on engine exhausts and compressor components. Mufflers or silencers can be used on noisy, pressurised air equipment to reduce noise at the source (OSHA Technical Manual 2014: 73). Generators during load shedding in kitchens to run lights, fans and some appliances can be muffled to reduce noise.
- Installing acoustic enclosures for equipment casing that radiate noise: refrigerators, ice machines and air coolers can be muffled to reduce noise in kitchens
- Improve the acoustic performance of constructed buildings by apply sound insulation. Sound insulation during construction and finishing for ceilings and walls can be covered with acoustic tiles.
- Installing vibration isolation for mechanical equipment. Grinders and blenders especially ice crushers can be installed on tables with vibration pads to prevent noise transmission to floor.

- Installing acoustic barriers without fissures and with an uninterrupted lower surface density of 10 kg/m² to minimise the transmission of sound through the walls. Barriers should be positioned close to the source to be effective. According to Noise Help (2019: 1), acoustic doors can be installed between the kitchen and dining room or a double door system or heavy fir door can be installed to prevent noise transmission from outside. Soundproof French doors or double glazed windows can be installed.
- Developing a mechanism to record and respond to complaints. Complaints from staff, customers and neighbours to reduce noise exposure should be attended to.

4.12.3 Behavioural guideline

Behavioural guideline proposed by the American Conference of Governmental Industrial Hygienists (ACGIH) as per Spellman (2006), includes additional guidelines that are pertinent to commercial kitchens envisaged in this study namely,

- Although hearing protection is preferred for any period of noise exposure > 85 dBA, the interval of noise exposure can be limited. For every 3 dBA increase in sound levels, the 'allowed' exposure extent should be decreased by 50 %. Shift work scheduled in rotation will reduce noise exposure as some shifts are less busy and hence less noisy; split shifts can reduce noise exposure.
- Preceding the distribution of HPDs as the final control mechanism, the use of sound shielding materials, isolation of the noise source, and additional engineering controls to be executed. Regular medical hearing testing to be completed on staff exposed to high noise levels (International Finance Corporation EHS 2007: 65-66). Change in management policy on hearing checks for kitchen workers will be useful. It seems regular maintenance of equipment will assist in lower noise levels in commercial kitchens.

4.12.4 Hearing-conservation programs

Kitchen workers suffering from NIHL can be administered with pharmacological intervention to prevent further hearing loss (Lynch and Kil 2005: 1291). There is a dearth of literature on hearing-conservation programs (HCP) in kitchens. Nonetheless, Kerns *et al*. (2018: 477) maintain that worksite health and wellness programs which include screenings for hypertension and elevated cholesterol to target noise-exposed workers.

Many HCPs are limited in their ability to control exposure to high-level noise, partly as a result of inadequate sound attenuation by HPDs. According to Lynch and Kil (2005: 1292), there is an urgent need to enhance current levels of hearing protection. However, HPD is inadmissible in the food service industry to avoid miscommunication, hence engineering design options during construction in kitchens is the solution.

If workers are exposed to noise levels at or above 85 dBA, an HCP should be established. The program includes a policy and procedure. The Standards Council of Canada (CSA Standard Z1007), Hearing Loss Prevention Program Management recommends that a hearing preservation program include the following elements:

- Hazard identification and exposure supervision
- Regulating procedures
- Hearing protection devices
- Hearing analysis
- Awareness and training
- Continuous monitoring and improvement (Standards Council of Canada 2019: 2).

Pimenta *et al.* (2019: 11) recommend that evaluation of the HCP efficacy be conducted as per the checklist proposed by the NIOSH. These HCP include physical, human and organisational assets, which assist in the application of methods that lead to detecting, analysing, monitoring and regulating the exposure of workers to higher noise and other risk factors, that may trigger the development of work-related NIHL.

4.13 Conclusion

Chapter four was a discussion on the sources of noise in kitchens, types of noise and adverse health effects of noise. It then discusses acoustic comfort, noise and productivity and demographics. It further deliberated on noise classification, NIHL, strategies for noise prevention, and noise reduction options in kitchens by a few engineering applications to kitchen appliances. It then urged for the implemention of HCP by employers for kitchen workers to minimise the sound levels in the workplace.

CHAPTER FIVE
LIGHTING

5.1 Introduction

The previous chapter focused on a review of indoor environmental criteria for the design of restaurant kitchens in Durban with respect to acoustics. The present chapter will present various aspects of light and its influence on human well-being. The discussions will show that visual comfort is dependent on a number of parameters such as type of light, contrast, glare and flicker. The chapter will conclude with regulations in kitchens and safety in the workplace. Opinions and debates from the literature on lighting will assist in attempting to compose indoor environmental criteria for the design of restaurant kitchens in Durban.

5.2 Lighting and quality of life

Pachito *et al*. (2018: 6) in a wider perspective, declare that exposure to light is crucial in a diversity of biological processes as it is linked to the human biological clock (Melanson *et al*. 2018: 49). Light has a massive effect on human physical and mental well-being as it is encoded in human DNA to perform better under specific lighting (Felderman 2017: 2). Ring (2018: 21) posits that natural light is preferable.

Lighting conditions can create responses, or so-called non-image-forming (NIF) effects, which can be either acute or circadian (van Duijnhoven *et al*. 2019: 152). Shishegar and Boubekri (2016: 155) accordingly claim that among many elements in the indoor environment, light seems to have the most impact on the human body.

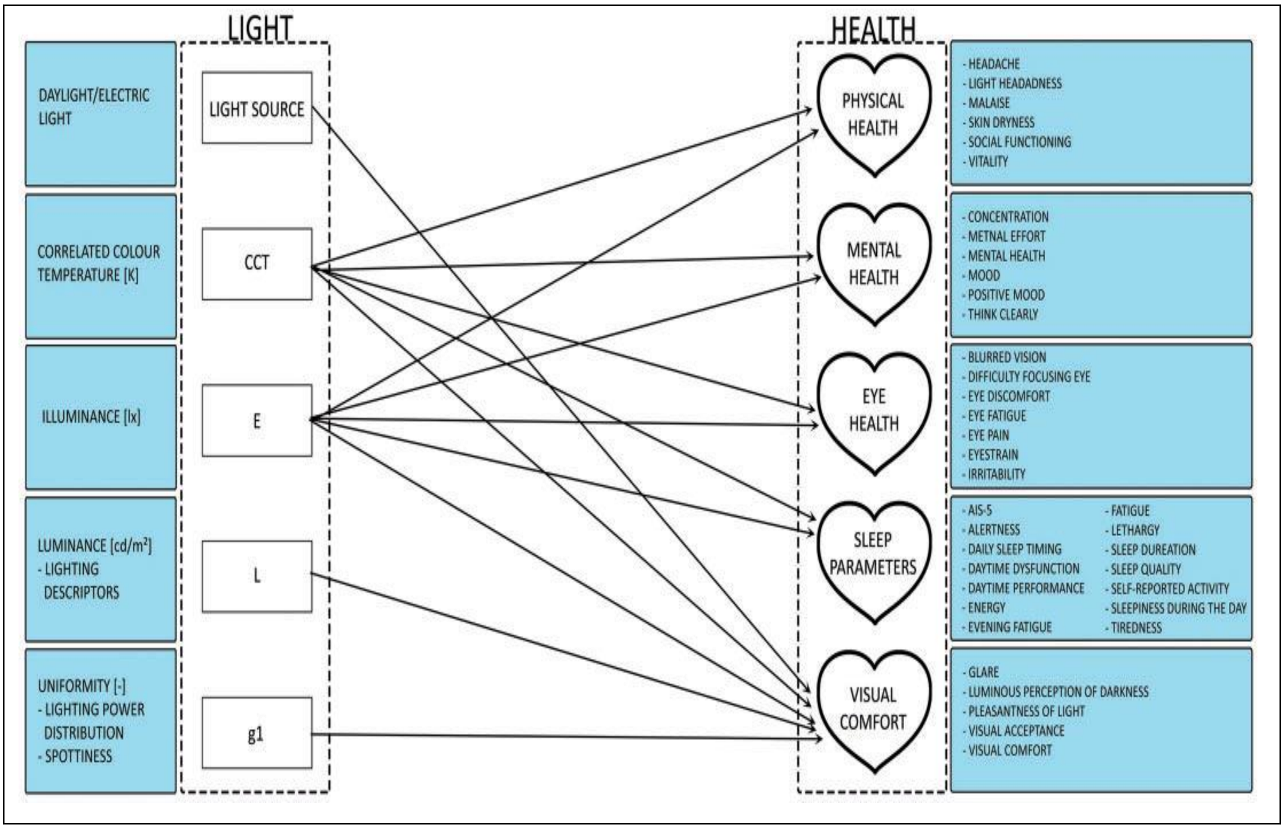
Artificial light is a compulsory feature of many man-made buildings and is required to extend daylight. However, artificial light can negatively affect human health and this is reflected in how it affects sleep, alertness, moods and biological and psychological processes (Morton 2016: 18). In this regard, the researcher suggests that this sentiment is likely to be shared by kitchen workers in Durban; the kitchen workers in basement kitchens and those on shift work may experience the adverse effects of circadian disruption.

5.3 Lighting and workplace

Figure 5.1 illustrates van Duijnhoven's *et al.* (2019: 169) review of the literature on the association of light with human health in the workplace. The investigation reveals that a majority of authors in the review whilst having a background in lighting, do not possess similar in health. The divide is unsurprising, as the fields of light and health research appear not to share technical knowledge.

Nonetheless, amongst the primary conclusions of relevance to the present study is that to improve the well-being of workers, workplaces should receive natural light as first choice and if necessary be complemented with appropriate electric lighting to support workers' safety and health, and to enable safe equipment operation in commercial kitchens. Additional task lighting may be required to meet specific visual alertness requirements.

Visual comfort is the absence of visual disomfort and capable of bestowing contentment in a work environment. The reviewed studies do not give any indication of the strength or significance of the correlation between the health indicator and the light conditions.



- Occupational health-related aspects

- Lighting parameters

- Interactions

Figure 5.1 Overview of association of light with human health (adapted from van Duijnhoven *et al*. 2019)

Subjective measures were mostly assessed using qualitative data sets, while objective measures were assessed using quantitative data sets, consistent with the approach in the present study. Table 5.1 illustrates the relationship between office lighting and health outcome categories such as physical, mental and eye health as well as sleep parameters and visual comfort.

Kruisselbrink *et al*. (2018: 42) declare that lighting quality is a concept that permits excellent vision while providing high comfort. The review by van Duijnhoven *et al*. (2019: 167), as illustrated in Table 5.1 (page 86) could not prove the effect of lighting on all the variables measured but indicate the effect with respect to physical and physiological health, mental health, eye health, sleep parameters and visual comfort. Lighting parameters such as illuminance, CCT, luminance, uniformity of light, and sources of light could influence kitchen workers in their workplace.

Notwithstanding, no published work is available regarding lighting in kitchens or the effect of lighting on kitchen workers. Concentration and mental health of workers can affect work performance in the kitchen. Singh *et al*. (2020b: 106) find that classroom lighting between 250 and 500 lux is correlated with increased concentration of students and improved performance. Tiredness and sleeplessness caused by a troubled sleep pattern frequently occurs amongst shift workers and may lead to the so-called shift work disorder (Richter *et al*. 2016: 2).

5.4 Daylight and artificial light

Christofferson (2011: 3) opines that the biological effect of light is due to the amount of light in the eye, and the difference in contribution within the room between daylight and artificial light. The use of combinations of daylight and artificial light is commonplace in the kitchen work environment. Hammer and Holzer (2020: 980) urge the need for deliberately designing indoor environments for sufficient daylight quality for all climates of the world. In this regards, Jensen (2019: 1) adds that natural lighting renovations result in cheerful staff and reduced sickness that leads to improved output. The approval of the new European Standard EN 17037-Daylight of Buildings (2018) deals exclusively with the design and provision of daylight.

Daylight is the optimal source of illumination either through glass curtain walls, large windows, or skylights. Nabil and Mardaljevic (2006: 905) lament that natural light is a greatly under-exploited natural resource; daylight always has the potential to displace all or part of the artificial lighting and is valued by workers. The authors, however, caution that if the daylight illuminance goes below 100 lux, it may not be adequate for the visual environment and performing visual duties. In the International System of Units (SI), one (1) unit lumen/square meter is a lux (Sebitosi and Pillay 2007: 675). The researcher posits that all primary roles and functions of kitchen personnel involve visual tasks.

The authors add that 86 % of office workers in England and New Zealand considered natural lighting to be their favoured source of lighting as natural light results in less stress and discomfort. Most indoor occupants state that natural light is better for emotional comfort, satisfaction, general well-being, visual health, and colour appearance of people and furnishings (Minnon 2019: 1).

Table 5.1 Summary of the relationship between lighting conditions and occupational health categories

Physical and physiological health	Mental health	Eye health	Sleep parameters	Visual comfort
1. Light source - daylight or electric light does not influence feeling healthy nor physical well-being;	1. Light source- daylight or electric light does not influence mood.	1. Light source- daylight or electric light does not influence eyestrain.	1. Light source (daylight/electric light) does not influence alertness, a disrupted biological clock nor sleepiness during the day.	1. Light source- daylight or electric light influences glare, luminous perception of darkness and visual acceptance. It does not influence the luminous perception of brightness.
2. Correlated colour temperature (CCT) influences fatigue, light-headedness and vitality, but does not influence headache	2. Correlated colour temperature influences concentration, mental health, positive mood, social functioning, and thinking clearly. It does not influence negative mood and memory.	2. Correlated colour temperature influences blurred vision, difficulty focusing, eye discomfort, eye fatigue, eyestrain and irritability.	2. Correlated colour temperature influences alertness, daily sleep timing, daytime dysfunction, daytime performance, energy, evening fatigue, lethargy, sleep duration, sleep quality, self-reported activity, sleepiness, during the day and tiredness.	2. Correlated colour temperature influences the pleasantness of light.
3. Illuminance influences headache, malaise, physical well-being and skin dryness	3. Illuminance influences mental effort and mood.	3. Illuminance influences eye pain.	3. Illuminance influences AIS-5 (Athens Insomnia Scale). It does not influence AIS-3 (sleepiness during the day)	3. Illuminance influences glare, the pleasantness of light.
				4. Luminance influences glare;
				5. Uniformity influences visual acceptance and visual comfort.

The access to daylighting, as well as artificial lighting, is nonetheless, vital to ensure the well-being of occupants in areas where daylight is absent or when the daylight fades (Al-Ashwal and Hassan 2018: 97). The authors add that appropriate daylighting designs help maintain good health, reduce stress levels of employees and alleviates headaches.

5.4.1 Windows

The presence of windows in the workplace and access to daylight have been linked with increased satisfaction with the work environment (Joseph and Ofresear 2006: 1) and enhanced hormonal balance (Jensen 2019: 1). The vertical illuminance at a window by Aries (2005: 56) illustrates that more illuminance at the window means more illuminance indoors. Al-Tamimi and Fadzil (2009: 374) consequently posit that windows can also have a strong influence on the use, productivity and comfort of the people who occupy the building.

Nisbets (2019: 3) maintains that windows in the kitchen should preferably be less than 10 % of the total floor area, looking out to the sky or open spaces. Such locations support the emphasis of Al-Tamimi and Fadzil (2009: 374) on natural light. Hence, Wang and Boubekri (2009: 23) claim that workers favour working near windows or in workplaces with daylight, a claim confirmed by the investigation of Hedge and Nou (2018: 1), about daylight, visual environmental effects of work, satisfaction, health and well-being and upheld by the correlation study of Hwang and Kim (2012: 75). Therefore, not surprisingly, Torres (2018: 1) adds that getting the seat by the office window is a coveted prize.

Windows according to Marcheso-Moreno (2019: 1), offer sunlight that has positive effects on workers' subjective well-being; however, access to natural lighting is not always possible for many workers due to the nature of modern work with 24/7 work, shift-work, non-routine work and diverse topographical latitudes. Hence, deep rooms and work-stations placed too far from a window could have negative health effects (Christofferson 2011: 3). Velux (2017: 1) recommends windows as sources of illumination and sun provision in buildings for promoting healthy indoor environments. Sonae Arauco (2020: 1) adds that possibilities for more natural light into an internal space include installation of skylights and glass sliding doors.

One of the most positive aspects of having a skylight is that it brings extra daylight into a room; increases natural light from skylights and reduces the use of artificial lighting and electricity (Reggev 2017: 3). The undisputable favour for windows is well known. Kaida *et al.* (2006: 462) show that exposure to natural light through a window enhanced feelings of pleasure and reduced soporific effect during light exposure. The depth of direct sunlight infiltration into the offices during summer according to Hwang and Kim (2012: 75) reduces the visual discomfort ratio to the lowest.

5.4.2 Artificial lighting

Apart from the advantages of health and well-being for the workers themselves, the overall effect of effective lighting is better productivity. However, Munch *et al.* (2020: 65) finds subjects exposed to electric illumination suggestively drowsier at sunset. Unlike natural lighting that varies throughout the day due to the weather conditions and position of the sun, artificial lighting is constant in both illuminance and colour temperature. Accordingly, preferences for artificial lighting varies with weather type, brightness and time of the day (Kort and Smolders 2010: 345).

Van Bommel's (2012: 5) recommendation of at least 1000 lux on the eye is for biological stimulation. Pasculescu *et al*. (2019: 287) believe that the visual comfort of workers can be ensured by inducing positive sensations during activity with artificial lighting such as fluorescent tubes and LED. Glickman (2019: 2) developed new evidence-based LED technology that operates with blue-enriched (BE) architectural lighting for optimising circadian rhythm and acute arousal effects of light. In the absence of prior investigations on the commercial kitchen's use of artificial lighting, the researcher advances a likelihood that all the commercial kitchens use artificial lighting in the day with or without the presence of daylighting.

Florescent lighting has adverse effect on workers, as it has been known to cause eyestrain and initiate headaches (Pochepan 2017**:** 1) and affects the well-being, performance and physiological arousal of workers as per a past study by Kuller and Laike (1998: 1655). Harsh lighting also creates problem for the eye to focus. Most people cannot notice the flicker in tube lights with a flicker rate of 120 Hz (Government of Canada 1978-2018: 1). It is vital to realize the impact of artificial lighting on worker well-being and performance directly or indirectly.

The preceding evidence raises a need to comprehend how the use of artificial lighting affects employee comfort. The need is further underlined in Aries' *et al.* (2010: 533) report of the inverse correlation between light level and employees' level of fatigue and sleep quality. In contrast, Fostervold and Nersveen (2008: 192) claim that there is little evidence of a direct impact of direct light or indirect light on health, well-being, or cognitive performance of office workers. However, Gabel *et al.* (2013: 1) proved that dawn stimulating light may provide an effective strategy for enhancing cognitive performance, well-being and mood.

The simulation of natural light is believed to attract some of the earlier mentioned benefits of natural light to worker well-being. Although compact fluorescent lamps (CFL) and incandescent bulbs remain the most widely used artificial lighting, light-emitting diodes (LEDs) have become more conspicuous in the field of lighting. LED lights are energy-efficient and have a very low power consumption with a full range in colour from warmer hues to white closer to daylight (Eartheasy 2020: 1). The number of light sources, particularly artificial lighting may be reduced using more efficient lighting fixtures and electronic ballasts such as upgrading T12 and T8 fluorescent tubes with T5 tubes (Tassou *et al.* 2011: 147).

Notably, in this regard, Jiang *et al*. (2019: 4065) have invented a wireless ballast-less lighting system for CFL that operates with remote lighting control via Bluetooth. It is too early for empirical discussion of health benefits or any disadvantages as the product is still new.

5.4.3 Harsh lighting and dim lighting

Harsh lighting, along with dim lighting, is equally detrimental to the well-being and productivity of workers. Jensen (2019: 1) contends that dim lights can be unfavorable to productivity for several reasons such as causing eyestrain and migraines since the eyes are required to exert much harder in poor light. Low lighting can also cause sleepiness and loss of concentration that would have an undesirable effect on worker productivity (Charlotte 2017: 1). In the kitchen, the main workstations have their own light sources as in the ventilation hoods with built in lights (Ring 2018: 22). Very bright indoor lights can be harmful to the eyes (Dunaief 2018: 1).

5.4.4 Flicker and glare

Flickering lights are observably distracting and create unpleasant working conditions as observed by Silvester and Konstantinou (2010: 11) who claim that the flicker produced by fluorescent lighting leads to visual discomfort. Flicker from LED lights may be more noticeable it seems, therefore, from a worker well-being perspective, fluorescent lights are not appropriate for commercial kitchen.

Disability glare arises from an extreme non-uniform distribution of light in the visual field, which is an impediment to the visual system and thus reduces the visibility of the scene (Fotios and Johansson 2019: 121). The researchers consider such impediments hazardous to workers in a commercial kitchen environment. In this regard, Hwang and Kim (2012: 87) find that after making improvements to alleviate the causes of visual annoyance, as well as the application of glare and shade control, the worker visual annoyance ratio decreases tremendously. Therefore, individual light fittings are not favourable in kitchens as different task stations are shared by several workers.

Insufficient light or glare reduces the ability to see objects or details clearly (Al-Horr *et al.* 2016: 7). It seems that glare in the kitchen occurs due to bright shiny work surfaces. Costanzo *et al.* (2018: 17) posit that daylight illuminance higher than 2000 lux is known to be strongly associated with occupant discomfort and glare risks. Fostervold and Nersveen (2008: 175) report that lower glare and decrease in flicker improved lighting quality and led to lower job stress severity, lighting from multiple sources reduced glare.

5.4.4.1 Prevention of glare

Balogh (2008: 60 cited in Ring 2018: 21) contends that strong lighting can create glare because the objects in the room have highly reflective surfaces, especially in kitchens, since the equipment is made of polished stainless steel. Strong glare can be distracting, and may even have a blinding effect, which is dangerous in kitchens. Objective glare indexes are associated not only with subjective visual comfort but also with non-visual functions such as subjective physical well-being and alertness (Borisuit *et al.* 2011: 1).

Fostervold and Nersveen (2008: 175) report that glare control requires lighting installations that use unique combinations of indirect and direct lighting. The researcher contends that such an optimal combination is necessary given the various tasks and work areas of a commercial kitchen. Windows may induce daylight glare and decrease indoor visual comfort. An associated implication demonstrated by studies that found people closing their window blinds to control unwanted glare (Wang and Boubekri 2009: 16). Yao (2014: 25) reveals that new mechanical venetian blind, can protect occupants from solar glare and maximises light diffusion into buildings.

5.5 Colour of light

According to Boduch and Fincher (2009: 4), colour relates to a specific frequency of light, and colour of lighting can have an affect on a person’s mood and work performance (Kuller *et al.* 2006: 1456). Mills *et al.* (2007: 2) and Viola *et al.* (2008: 297) found a positive effect of a high colour temperature of 17 000 Kelvin (K) on workers.

Kitchen workers from different cultural backgrounds and ethnicity may associate with similar lighting colours differently. Common lighting, such as incandescent and fluorescent lighting, falls within the red to green colour range, whereas daylight falls in the light blue to blue colour range (Lumens 2020: 1). This means that the illumination presently used in interiors has a precise opposite warmth than natural sunlight and gives the eye a different range of colour. This is the reason why individuals often need to take a moment to let their eyes adjust when walking into a lighted interior from direct sunlight. Hence, dimly lit storage rooms leading from kitchens or gas cages in bright outdoor spaces creates a temporary blinding effect that could cause accidents in kitchens.

Task lighting is a common feature in commercial kitchens. Van Deusen (2019: 1) reasons that neutral colour temperature, slightly toward the cooler side of 4 000 K, would be best for kitchen task lighting. This should be augmented with fill light so that the work surface is well lit and difficulties with shadows are kept to a minimum. Lighting over 6 500 K gives a bright blue light hue and is used mostly for task lighting to measure colour temperature (Lumens 2020: 1). However, Morton (2016: 18) claims that inappropriate lighting can lead to poor colour rendering. Sethi and Malhan (2015: 71) argue that commonly used fluorescent tubes do not give particularly good colour effects and not recommended for kitchens as the colour of food is masked.

Colour Rendering Index (CRI) is a measurement of the light's ability to show an object's colours naturally in reference to a source like daylight (Zumtobel 2018: 18). The CRI of modern kitchen lighting is important. The better the CRI value, the more realistic food colours will appear to kitchen workers (Houzz 2019: 2). Warehouse Lighting (2020: 1) contends that in kitchens, a higher CCT can help a chef arrange an attractive artistic food on the plate. Another approach is to equal the CRI at the plating area to that of the CCT in the dining area and perceived by the customer when receiving the plated food to create consistency. CBMC Lighting Solutions (2017: 2) report that in higher-end restaurants, the CRI is particularly significant as food presentation is an art. Higher CCT and CRI would help kitchen workers to a comfortable atmosphere and a good vision for plating food (Die-Pat 2016b: 3).

5.6 Lighting and health

As alluded to in prior sections, kitchen lighting has definite implications for kitchen worker health. Kralikova's *et al*. (2016: 1) review states that good lighting in the workplace with well-lit task areas is essential for optimising visual performance, visual comfort and ambience, especially with an ageing workforce.

Viola *et al*. (2008: 297) report that white light improved the subjective measures of alertness, positive mood, fatigue, performance, irritability, concentration and eye discomfort. This would assist with design lighting strategies to maintain health, productivity and personnel safety (Najjar *et al*. 2014: 8). Aries *et al*. (2015: 7) accordingly claim that daylight has been linked with higher attendance, reduced tiredness, respite from SAD, diminished unhappiness and skin disorders, enhanced vision and beneficial effect on the degenerative diseases of brain. Pachito *et al*. (2018: 3) concludes that cool white light may improve alertness, may cause less irritability, eye discomfort and headache.

The counteracting behaviour such as moving closer to cope with vision difficulties is clearly linked with dry eye symptoms (Lin *et al.* 2019: 7). Employees with years of experience at work and having shorter breaks were more likely to develop eye fatigue. This observation is very likely to impact on kitchen workers extended work hours.

5.6.1 Physiological and hormonal effects of light

According to van Bommel (2006: 461), light mediates and controls several biochemical processes in the human body. The biological effects are dependent on the colour temperature, light level, duration and timing of exposure, as well as on the size and position of the light source and is likely to influence individuals' well-being, health and performance. Rossi (2019: x) nonetheless contends that daylight provides better illumination for the synchronisation of the biological clock. Kumar *et al*. (2020: 177) claims that illuminance and circadian lighting design are interrelated with each other. A disturbed biological clock among kitchen workers due to shift work or harsh lighting can cause sleep disorders, reduced energy levels, tiredness and lethargy. Eyestrain, blurred vision, irritability can be caused by dim or harsh lighting in kitchens.

In this regard, Rea and Figueiro (2018: 497) adopt circadian stimulus (CS) as a metric for quantifying light in architectural spaces. This metric is not suitable for kitchen workers in Durban, as most restaurant kitchens do not operate at midnight hours until early morning.

Millett (2014: 1) compares seasonal affective disorder (SAD) with jet-lag as sufferers show symptoms due to the shifting of the circadian rhythm with respect to their daily routine. SAD is present at a low level for many people working in poorly lit buildings. According to Parekh (2017: 1), the SAD is a form of winter depression. The symptoms can be distressing and overwhelming due to shorter daylight hours and less sunlight in winter. As seasons change, people experience a shift in their internal biological clock that can cause them to be out of step with their daily schedule. The researcher opines that kitchens with low lighting levels may affect workers' alertness and cause SAD as bright sunlight is accessible once outside in the sunshine. Marć *et al*. (2018: 2071) report that kitchens are usually located on the lowest floors of the building, which results in a very small number of windows.

The significance of lighting is inferred in treatment with light for patients having SAD (Lam 2009: 39). Maierova *et al*. (2016: 2) maintain that daily environmental light exposures provide the strongest influence for the circadian system to adjust the 24-hour endogenous rhythm in humans to external clock time, light has modulating effects on work performance, perception of well-being, mood and sleepiness. Acute reactions include fluctuations in melatonin secretion, core body temperature, heart rate, brain blood flow and cognitive performance, whereas circadian include circadian phase shifts and changes in sleep patterns, which over time might lead to specific behavioural disorders (van Duijnhoven *et al*. 2019: 152).

5.6.2 Alertness and sleep

Lighting has an important influence on alertness and stress. For example, daytime workers may be exposed to insufficient or inappropriate light, leading to mood disturbances and decreases in levels of alertness (Pachito *et al.* 2018: 1). British Columbia Campus (2020: 1) warns that kitchen workers must stay completely alert on the job and when carrying china and glassware from one place to another.

Hima Bindu and Reddy (2013: 1320) reported that lower lighting levels during daytime affected sleep quality of cooks during the night, with disturbed sleep and alertness. Ruger *et al*. (2005: 211) concluded that light levels have a positive effect on subjective alertness. The author further postulates that light levels affected heart rate and core body temperature. Aries (2005: 8) find a significant correlation between the vertical illuminance at eye level and the parameters 'fatigue' and 'sleep quality'.

Phipps-Nelson *et al*. (2003: 695) found that bright light decreases sleepiness and improves psychomotor vigilance performance. Bright light increases heart rate and core body temperature only during night exposure. BE white light can enhance attentiveness and avert fatigue-related behavioural decrements of vigilance, while accuracy in complex tasks necessitating precision may deteriorate (Rodriguez-Morilla 2018: 11). Choi *et al.* (2019: 1) find that BE-LED light seems to be a simple yet effective potential countermeasure for morning drowsiness and the decline of melatonin levels significantly improved the subjective perception of alertness. However, Parker-Pope reports in The New York Times (2010: 1) that a medical doctor cautions against blue light that may be a greater trigger for migraines and old fluorescent lights emit blue light.

5.6.3 Cognitive and psychological

According to Woofter (2014: 3), lighting plays a huge factor in how a person perceives the workplace due to its psychological effect. The author adds that the right fixtures can even foster creativity, boost morale and encourage communication. Black and Decker (2009: 242) emphasise that the main objective should be about comfortable and effective illumination by setting the right fixtures in the right places and about maximising natural daylight.

Hence, visual effects are perhaps the most phenomenological of all the comfort categories (Boduch and Fincher 2009: 4). For example, lighting a ceiling can make a space feel brighter. As kitchens are not accessible to customers, the researcher strongly feels that it is pointless in creating themed lighting, which may cause eyestrain among workers.

Silvester and Konstantinou (2010: 11) illustrate the effect of colour on behaviour of children in Germany, pre teens (8-12 years old) were more positively disposed towards a reddish light that pacified them with a decrease in hostile behaviour. An increase in pro-social behaviour by the participating students ensued in better reading and greater reading speed and fewer errors. The psychological effects of lighting suggest that high illuminance and high colour temperature can have positive effects on people's well-being, health and performance (Knez 2001: 201). It accordingly appears that lighting above the specified minimum lighting requirements of various World Standards in different kitchen areas can have a positive influence and reduced errors among kitchen workers. It seems that the more intense the task, the brighter the light required. This is the main reason surgical operating rooms with 1 000 lux are much brighter than offices (Thuillier 2017: 2).

5.6.4 Visual comfort

Thuillier (2017: 1) defines **v**isual comfort through a set of criteria based on the level of light in a room, the balance of contrasts, the colour 'temperature' and the absence or presence of glare. Visual comfort along with other elements, essential for the well-being of the occupants in buildings (Serghides *et al.* 2015: 528). Lighting in kitchens should provide greater comfort to the eye (Simone *et al.* 2013: 1001).

The best combination of factors to optimise well-being and the feeling of comfort includes the quantity and quality of light into a building, quality and access to views from inside the building and the quality of the surrounding space. Giarma *et al.* (2017: 522) compared visual comfort criteria by different standards and reviewed building environmental performance assessment tools and methods focussing on visual comfort aspects - daylight, illuminance and lighting controllability.

As purported by Leech *et al.* (2002: 426) and supported in Table 5.1, visual comfort defines lighting conditions and the views from one's workspace. Visual comfort at work has an impact on comfort after work as well (Al-Horr *et al.* 2016: 7). Serghides *et al.* (2015: 528) show that the impact of visual comfort on sleep quality at home after work is influenced by gender, age and seasons. Visual comfort seems to include the optimal permutation of illuminance levels, luminance ratios and colour temperature. Buildings need to avoid excessive use of artificial lighting yet still maintain some level of optimality (Yun *et al.* 2012: 146). Therefore, daylight, artificial lighting, glare and visual comfort should be structured and designed together to obtain a more holistic picture (van Den Wymelenberg and Inanici 2014: 145).

5.7 Performance and productivity

Good lighting enhances people's sense of well-being, improving concentration, motivation and performance (Kralikova's *et al*. 2016: 1). Workplace illumination is an important parameter influencing worker's productivity in terms of speed, quality of work, downtime, absenteeism and accident rates (Hoffmann *et al.* 2008: 719). Also, there exists a strong relationship between illuminance and task completion times (Sanjog *et al.* 2013: 510). Hence, it seems that additional lighting such as improved general lighting, task lighting and personal control of lighting to improve lighting levels in kitchens would improve the work performance of cooks.

In this regard, Juslen *et al.* (2007: 42) report that production speeded up in an environment having 1 200 lux by 9 % more when compared to 800 lux. Greenberg (2017: 1) later confirms that lighting plays a major role in employee productivity. Tetlow (2007: 174) relevantly recommends individually controllable task lights, that is critical for kitchen work.

High-intensity and high-quality lighting provides more adjustment between the person and their work environment (Newsham *et al.* 2009: 129). Controversially, Akbari *et al.* (2013: 4) reported that the amount of lighting did not have any influence on human productivity. According to Sinoo *et al.* (2011: 1918), too much luminosity in working stations caused a decrease in human performance and productivity. Boyce *et al.* (2006: 217) however, argues that whilst the goal of creating high-quality lighting to improve organisational productivity is more challenging, investments in lighting to create a productive workplace will pay off in the end.

5.8 Demographics

The demographic characteristics of human beings and therefore, kitchen workers have a mutual relationship with their well-being. For instance, the age and gender of kitchen workers are impacted upon by the lighting conditions in the kitchens, as will be presented in the sections that follow.

5.8.1 Age

As per the American Optometric Association (2020: 2), eyes and vision change over time, and employees require more brightness to see. Nylen (2017: 90) asserts that the prevalence of visual problems and eye diseases increases in the age group of 65 and older; early diagnosis and treatment can reduce not only the risk of accidents but also increase the working capacity and well-being. Hence, workplace lighting plays a significant role in improving task performance among elderly (Silvester and Konstantinou 2010: 16).

Higher lamp lumen levels are necessary to special age groups of occupants (Sebitosi and Pillay 2007: 676); age-related increases in illuminance preference would be consistent with known age-related decrements in vision. Kunduraci (2017: 185) posits that the eye of an average 60-year old requires three times more illuminance than the eye of an average 20-year old.

5.8.2 Gender

Gender differences by Lee *et al*. (2013: 37) reveal that women, when compared to men, were more likely to perceive lighting as an important factor in their everyday lives, showing a preference for incandescent lighting, and perceiving fluorescent lighting as having adverse effects on human health. Hence, gender differences in light sensitivity might play a key role in ensuring the success of individually targeted light interventions in kitchens. Yang and Moon (2019: 628) find that women had higher scores for visual comfort with 500 lux than those of men with statistical significance.

Chellappa *et al*. (2017: 14215) however, report that not only do men have higher brightness perception and faster reaction times in a sustained attention task during BE light but also had improved sustained attention performance compared to women. The physiological reason for women's higher lighting requirements than men is that they are born with fewer cones and rods that are light receptors (Owen 2012: 2).

Dry eye symptoms are common among women and shown to increase with age Nylen (2016: 91) and Jeng (2018: 2). Women have an increased risk of glare, as the eye position is slightly further down. Visual impairment is also more common among women than men, which can have both biological and socio-economic causes (Zetterberg 2016: 19) and this could be due to the longer lifespan of women, as well as the increased risk of cataracts, and age-related macular degeneration contribute to this condition.

5.9 Lighting in food service kitchens

Balogh (2008: 61) claims that in an area where food is being prepared, effective natural or artificial lighting conditions should be provided. It is essential to have strong lighting of 350 lux, as the cooks continually rely on their vision to assess the quality of the food, the ingredients, to steer through the kitchen and to use kitchen equipment and tools appropriately. Kitchens are often too large to be illuminated entirely by natural light, as glare and shadows are going to be a perpetual problem (Balogh 2008: 61). Moreover, commercial kitchens require direct lighting where preparation is going to take place such as worktops, sink and stoves that will ensure that all chopping and cooking is done safely, without shadows. Kitchen countertops in Turkey require a minimum of 500 lux (Kunduraci 2017: 190). Colin (2011: 1) however, recommends 750 lux. Lamps with high CRI are preferred in the kitchen area. Hence, Kunduraci (2017: 190) posits that the various tasks such as preparation, cooking, cutting, washing and eating are completed in kitchens. In order to fulfil the visual requirements for each task, layered lighting design can be applied. Each task can be well-lit by task lightings that prevent glare or dark shadows. The author recommends maximising daylight in the kitchen area as much as possible to provide an adequate amount of light. However, if glare is a risk, shading can be used to prevent undesirable reflections.

Almeida *et al*. (2014: 343) found that urban Brazilian food services had lower compliance rates (2.7 %) in municipal schools with lighting requirements. Interestingly, adequate lighting is reported in (185/420) 44 % of food establishments in Ethiopia (Kumie and Zeru 2007: 3). Laikko-Roto and Nevas (2014: 67) in Finland revealed that restaurant business operators rated lighting in kitchen and storage areas as 8.4, whereas the food control officials rated it as 6.7 on a scale of 1-10. There appears to be no published study of kitchen lighting in South Africa.

Eagles and Stedmon (2004: 442) find the need for extra lighting especially in food preparation areas where workers might be doing delicate tasks with sharp knives. Corncerningly, Omidiandost *et al.* (2015: 257) report from Iran that the lighting in a hospital kitchen measured only 148 lux instead of the expected 250 lux in food services. The researcher suggests that such inadequate lighting in kitchens is not conducive to the well-being of kitchen workers. Die-Pat (2016b: 4) adds that safety of workers is enhanced if they can see every detail of their work while using sharp knives and other relatively dangerous cooking equipment. Gaydos *et al*. (2011: 62) report that 28 % of 106 restaurant kitchens in San Francisco's Chinatown lacked adequate lighting. Any shortcoming in lighting adequacy has knock-on effects for well-being and consequently, performance. Hima Bindu and Reddy (2013: 1321) add that 62.2 % of cooks in Indian commercial kitchens report that the workers often experience eyestrain and irritation. A well-lit workspace is uplifting, encouraging workers to see their work environment as positive and motivating them to do their very best (Die-Pat 2016b: 4).

In general, there is migration from fluorescent and incandescent kitchen lighting. Instead, LED lighting in the open kitchen may be carefully tuned for optimal function while creating a warmer feel (Gordon and Zeigler 2017: 3). As the kitchen is a very hot working environment, choosing a low heat emitting light such as LED will produce little heat and is remarkably bright for the working area (Die-Pat 2016b: 4).

In order to design an effective lighting environment, the target lighting conditions must be considered from many dimensions, including light levels such as illuminance and luminance, control of glare, distribution, uniformity and light source cooler (Hwang and Kim 2012: 87). Webstaurant Store (2018: 1) states that task lighting allows staff members to perform functions that may need a more concentrated light source, like cooking. It can take the form of overhead lamps and bright fluorescent lights in a kitchen. Directional and accent lighting can reduce glare and increase contrast and is considered a good idea in modern kitchen lighting (CBMC Lighting

Solutions 2017: 2). However, Webstaurant Store (2018: 1) claims that accent lighting has a dramatic effect on kitchen space and generally not used in kitchens.

5.9.1 Lighting classification

A classification of lighting for kitchens to address ergonomic needs appears not to be available in the literature. However, two related classifications are reflected in Table 5.2. These are drawn from:

1. Classification of artificial lighting and

2. Classifications of light fixtures according to lamp types, installation, percentage of light output above and below the horizontal.

It seems evident in that the lighting variations in Table 5.2 are commercial kitchens; these must meet the requirements of OHSA (No. 85 of 1993) as per South African Legal Information Institute (1993). For example, all food-grade lightings should be shatterproof and or protected. Die-Pat (2016b: 2) recommends that extremely high temperatures found in many kitchen areas such as near ovens and stoves can often result in bulbs shattering. Installing shatterproof bulbs protects employees from injury when shattered glass either cuts them or gets into their eye.

Table 5.2 Summary of classification of lighting and lighting fixtures (by researcher)

Basic types of lighting	Artificial light sources	Types of lighting lamps	Determinants of Indoor lighting fixtures
American Lighting Association (2017) and Levison (2019)	Electrical Knowhow (2013)	US Department of Energy (undated)	US Department of Energy (undated)
1. Ambient	1. Incandescent lamp	**1.** Fluorescent-industrial linear	1. The light function
2. Task	2. Compact fluorescent lamp	2. Incandescent-cool white light bulb	2. Lamp type
3. Accent	3. Fluorescent tube	3. Outdoor solar-not suitable for kitchen	3. Installation method
	4. Discharge lamps 5. Light-Emitting Diode (LED)	4. Light-emitting diode (LED)-ingress LED panel or LED downlights	4. The percentage of light output above and below the horizontal

Commercial kitchen lighting belong to ambient or general, accent and task lighting classification (Levison 2019: 1). Ambient lighting is a necessary part of any good lighting plan because it provides an overall brightness to a room and creates enough light to see and move around comfortably and safely. The role of general lighting is to illuminate the entire kitchen, to provide sufficient visual conditions for the users to navigate through the room and to see the contents of any shelves, cupboards and drawers (Balogh 2008: 62). The problem with general lighting is that kitchen workers have to accomplish several tasks with backs to the light source that casts a shadow on the workstation; hence, functional lighting is needed. The author adds that functional lights provide light for individual workstations where the strength of the general light is insufficient, as kitchen work requires excellent lighting.

Task lighting focuses on a specific area to provide targeted illumination for accomplishing tasks (Lightology 2018: 1); allowing the option to adjust the lighting for a workspace or chosen area. Black and Decker (2009: 257) claim that task lighting provides focused light in specific work areas, such as the cooktop, sink and countertops. Ambient and task lighting together make up the core of a kitchen plan. Los Alamos National Laboratory Sustainable Design Guide (2018: 87) recommends that to help maintain visual comfort, task illumination must not be more than three times that of ambient illumination. Effective task lighting needs to reduce glare and should be bright enough to prevent eyestrain, making it ideal for activities like, cooking, studying and work (Levison 2019: 1). Accent lighting creates a focal point, appears pointless in commercial kitchens.

5.9.2 Lighting standards for kitchens

Mikulka (2018: 1) claims that one of the main elements in lighting lies in generating a sufficient level of illuminance. Table 5.3 illustrates the various standards for illuminances for the range of kitchen tasks (HSG38 Lighting at Work 1997: 28) and CIBSE. Comparisons can be drawn with respect to variations in lighting levels in different areas of kitchens and whether the lighting levels meet the minimum requirements.

Table 5.3 (page 100) indicates the minimum standards. CIBSE has specified categorical lighting levels for every section in the kitchen. WHO also mentions the acceptable range of lighting levels. Other standards indicate lighting levels that pertain to certain kitchen tasks. An observable gap exists in standards for specific sections of the commercial kitchen such as salad preparation, sushi and meat section and or seafood section.

Table 5.3 illustrates that OHSA (South Africa) has the lowest lighting requirements compared to International Standards. The Occupational Health and Safety Brief declares that poor lighting at work can lead to eye-strain, fatigue, headaches, stress and accidents (ILO 2017). As mentioned earlier, too much light can also cause safety and health problems such as glare, headaches and stress and these could lead to mistakes at work poor quality and low productivity.

Glamox (2017: 1) states that a kitchen is a workplace for chefs and cleaners, and the illuminance and uniformity levels are, therefore, quite high. Importantly for the commercial kitchen environment, Ingress Protection rating is an international method used to describe the protection of a fitting to stop the penetration of solid objects or water entering the light fitting. Electrical Encounter (2019: 1) notably recommends ingress protection 20 rated products in the kitchen to avoid steam generated moisture and condensation or water drips.

According to Environmental Regulation Act (1987) and Occupational Health and Safety Act, South Africa (1993), food preparation areas in the kitchen need to have an illumination of 150 lux only in total contrast, significantly below the South African National Accreditation System (SANAS) that endorses 300 lux.

Table 5.3 Comparative illustration of International Standards

Activity Level of illuminance (lux)	OHSA (SA)	SANAS	CIBSE	BOSH	IES	OSHA (USA)	WHO	Australian Standards
Food preparation and cooking	150	500	500	500	300-750	500	300-500	500
Bakeries-preparation and baking	100		300					
Finishing, glazing, decorating cakes	200		500		300-750			
Dishwashing		300	300					
Storage		150	150		50-200			110-150

OHSA-Occupational Health and Safety Act

SANAS- South African National Accreditation System

BOSH-British Occupational Safety and Health

CIBSE-Chartered Institution of Building Services Engineers

IES-Illuminating Engineering Society

OSHA-Occupational Safety and Health Act

WHO-World Health Organization

This inconsistency can be perplexing to food preparation establishments, and this could lead to the increased possibility of wide deviations from recommended lighting standards in lighting in kitchens. The SANAS minimum standard is aligned to the other international standards such as WHO, Australian standards 1680, ANSI and CIBSE.

In South Africa, a code of practice (SABS 0114-1: 1996) offers the minimum lux for a range of workstations and activities. Kitchens are allocated 200 lux. In significant contrast, Eagles and Stedmon (2004: 442) recommend that the standard illuminance should be 500 lux for food preparation and cooking, 300 lux for serveries, vegetable preparation and washing up areas and 150 lux for food stores. Like other standards, there are similar country to country variations (Sebitosi and Pillay 2007: 677).

As per Archtoolbox (2020: 1), IES recommends lighting levels from 300 to 750 lux in kitchens. Further to preparation, cooking and dishwashing, intricate decoration of cakes, pastry work, desserts, confectionery, sugar and chocolate art in bakeries and cake shops also require appropriate lighting.

5.10 Lighting and safety in the kitchen

There is an obvious link between lighting and workplace safety namely, insufficient lighting leads to increased error rates, and in many cases, small or significant injuries **(**Silvester and Konstantinou 2010: 24). Poor illumination detracts from workplace safety in kitchens. If staff are unable to properly see the tasks performed, accidents and mistakes are more likely to occur. For example, sufficient lighting should be provided so that a kitchen worker can see the water spill on the floor to avoid a slip. If workers are unable to distinguish, for instance, the faces of approaching personnel, it could cause a security risk as their ability to recognise threatening behaviour is delayed (Morton 2016: 18). This implies that kitchen workers' safety and well-being is in jeopardy. Conversely, Carayanni *et al*. (2011: 199) state that factors such as inappropriate lighting, inter alia safety equipment and working time did not present significant associations with the risk of being injured.

This section on the literature review attempted to present a commercial kitchen discussion of how kitchen workers are affected by light and the significance of daylight. In doing so, it debated the need for artificial light, different types of lighting and health effects of lighting. It then proceeded to deliberate on how lighting requirements vary with age and gender. It further discusses lighting source suitability, the differences in kitchen lighting guidelines and safety from glare. Lighting, in conjunction with the parameters discussed in the preceding chapters, determines the extent of kitchen workers' well-being in the commercial kitchen environment. The section that follows will focus on the interrelationship between the various parameters and is often referred to as Indoor Environmental Quality (IEQ) in contemporary literature.

5.11 Interrelationships between the indoor environmental parameters

IEQ is increasingly recognised as a significant factor influencing the overall level of building occupants' health, comfort and consequently, productivity. Currently, there is no available broad statement on kitchen IEQ as no research in this area has been conducted. An in-depth survey of the literature has not revealed any evidence of a similar study. The current study may be considered ground-breaking research as it takes into account five IEQ parameters that influence worker well-being in commercial kitchens. Witterseh *et al.* (2002: 1083) study the same parameters but in an office environment. This study attempts to improve the well-being of kitchen workers in commercial kitchens by recommending improvements in environmental variables to enhance comfort in workspaces. Unlike the focus of the present study on six (6) parameters, there is empirical evidence of work in fewer IEQ parameters. Several studies on commercial kitchens discuss thermal comfort and noise only in separate studies as bivariate models and not as multivariate deliberations. Simone *et al.* (2013:1014), Rahmillah *et al*. (2017: 1), and Sajedifar *et al.* (2017: 4) do not report on lighting and noise in kitchens. The review that follows will progress from the relationship between two parameters to multiple parameters. As illustrated in Table 5.4, the combined studies of environmental ergonomics indicate a limited perspective on well-being but lean towards worker productivity instead.

Table 5.4 Selected studies with combined indoor variables (by researcher)

Source	Temp	RH	Airflow	CO_2	Noise	Lighting	Work-space	Location
	Thermal Comfort							
Witterseh *et al*. (2004:1084)	√				√			Open-plan office
Balazova *et al*. (2008: 7)	√	√			√			Simulated office
Vimalanathan and Babu (2014: 1)	√					√		Office
Tiller *et al*. (2010: 522)	√	√			√			Experiment chamber
Huang *et al*. (2012: 304)	√	√	√		√			Office with manipulations
Witterseh *et al*. (2002: 1083)	√	√	√	√	√	√		Open-plan office experiment
Hygge and Knez (2001: 291)	√	√	√		√	√		Experiment chamber
Huizenga *et al*. (2006: 393)	√	√	√	√	√	√	√	Buildings
Jimoh (2017: xx)	√	√	√	√	√	√	√	University buildings
Aziz (2015: 1)	√	√	√					Buildings
Heinzerling *et al.* (2013: 13)	√	√	√	√	√	√		Buildings
Barthelmes *et al*. (2020: 314)	√	√	√	√	√	√		Offices

Combined studies in Table 5.4 indicate that the six indoor ergonomic parameters investigated in the current study are not available in the literature. There are a few combination studies in offices and hospitals with varying degrees of researcher manipulations. These are discussed below:

5.11.1 Interrelationship between two variables

Occupants of a building must enjoy an internal environment that is considered acceptable for safe habitation. The performance of a building IEQ needs to be regularly assessed and evaluated. For instance, Naicker *et al*. (2017: 1) reveal the risk of extreme indoor air temperature in a study of two parameters, namely, indoor temperature and RH in Johannesburg. This section, therefore, presents bivariate studies of IEQ variables.

5.11.1.1 Temperature and noise

In combined studies of temperature and noise parameters, Witterseh *et al*. (2004: 30) and Balazova *et al*. (2008: 7) find that both affect the overall worker acceptability of the working environment. The authors add that the ability to concentrate decreased with a combination of elevated temperature and noise. Interactions of thermal and noise conditions are further raised as subjective worker acceptability decreases. Aziz (2015: 1) reports negative attitudes arising among the employees who are slacking off in hot and humid office conditions in Malaysia, along with a decline in productivity of employees; the influence of noise is not indicated.

Tiller *et al*. (2010: 522) summarise results from an experiment designed to investigate the combined effects of noise and heat task performance and thermal comfort can be affected by the acoustical environment. On the other hand, the subjective evaluation of office noise were unaffected by the thermal environment. The subjects showed a slight tendency to rate the thermal environment as being dissatisfied when the Room Criteria (RC) noise level increased from RC-30 to RC-50 (Tiller *et al*. 2010: 522).

Thermal quality was ranked as the highest contributing factor for overall satisfaction with IEQ in combined studies of air, visual and acoustic qualities. Frontczak *et al.* (2012: 23) report that the majority of survey studies showed that heat as a parameter was rated to be of considerable significance for attaining overall comfort than noise and lighting and IAQ. In agreeing Huang *et al*. (2012: 304) add that a organized field study to examine the satisfactory range of environmental factors, as well as the aggregate effect of numerous factors on IEQ along with combined thermal, luminous and acoustic indoor environmental parameters may account for the ranking.

Acoustics typically receives the lowest satisfaction rating in office buildings (Frontczak *et al.* 2012: 128). The authors report that when the acceptability of IEQ parameters are of a similar magnitude, corresponding to low levels of dissatisfaction from all indoor environment is estimated by averaging the appropriateness of these individual parameters. Results from the Danish residential buildings show that not only indoor environmental parameters contributed to residents' comfort but also a peaceful atmosphere, contact with natural surroundings and the view through a window (Frontczak *et al.* 2012: 4). Similarly at work, Frontczak and Wargocki's (2011: 934) survey showed that country of origin, level of learning, type of work, the psychosocial ambience at work and time pressure did affect the evaluation of the indoor environment.

5.11.1.2 Temperature and lighting

In an early pioneering study, Kuller and Laike (1998: 440) evaluate the impact of flicker from fluorescent lighting on comfort, performance and physiological alertness against the subjective responses to ambient temperature as a covariate. Kompier *et al*. (2020: 976) demonstrate a significant relationship between visual and thermal comfort, however, causality in this relationship could not be established. Vimalanathan and Babu (2014: 1) report that indoor room temperature (38.56 %) holds a greater impact on office worker's performance than the effect of illumination (19.91 %).

5.11.2 Interrelationship between three or more variables

Comprehensive consideration of all IEQ variables seems to be a better indicator of the influence of multiple variables on occupant well-being and building performance. The relationships between indoor building conditions such as thermal aspects, ventilation, lighting, humidity, mould and noise on well-being, such as health and comfort of occupants of office buildings, schools and homes, are complex and not easy to unravel.

Table 5.4 reveal studies on the effect of a few more parameters interacting together. Temperature seems to be a common parameter in studies of multiple environmental ergonomic variables. In this regard, it is pertinent that Wargocki and Wyon (2017: 359) claim that heat has the greatest influence on arousal or soporific effect and diminishes or alleviates discomfort levels caused by other variables. The discussion that follows outlines a selection of the studies.

To begin with, Huang *et al.* (2012: 309) investigate a combination of three individual environmental factors and report conclusions independently. When the noise level was below 49.6 dB, subjects felt satisfied with the acoustic environment. Furthermore, the highest level of satisfaction with the thermal environment occurred when the operative temperature was 25.7 °C. The subjects also felt satisfied with the luminous environment when the illumination intensity was above 300 lux (Huang *et al.* 2012: 309).

Hygge and Knez (2001: 291) earlier find that cognitive performance was affected by the interaction of ventilation, noise levels ranging from 38 dB(A) to 58 dB(A), air temperature at 21 °C and 27 °C, and illuminance from 300 lux and 1500 lux with humidity at a fixed level. Greater attention was observed due to noise but with lesser accuracy, which supports the Speed-Accuracy-Trade-off Hypothesis. The inference drawn was that even though there was a greater focus on completing the test, accuracy was compromised due to noise interference. The interactions between noise and heat and noise and light were not conclusive (Hygge and Knez 2001:291). Rupp *et al*. (2020: 813) find that men tend to perceive themselves more sensitive to heat therefore, it may not be a gender, but a psychological variable that should be considered when addressing individual differences on thermal comfort.

Montazami and Lunn (2020: 825) report on the influence of IEQ, the control aspect and individual influences on mounting stress symptoms among employees. The sensitivity of occupants towards thermal comfort, lighting comfort, acoustic comfort and air quality was evaluated with Environmental Stress Score (ES Score) that represents stress symptoms from IEQ. In another study, Witterseh *et al*. (2002: 1083) included multiple combinations of IEQ variables. Even though noise decreases concentration and increases fatigue, the noise was found to increase arousal states that counteracted the soporific effect of warm temperatures. Heat also increases fatigue and in addition, causes SBS symptoms of eye, nose and throat irritation and headaches. Similar symptoms were reported by Singh *et al.* (2016: 11) in commercial kitchens.

Ismail *et al*. (2010: 1300) assess the following variables: temperature, RH, lighting, noise levels and comfort levels of a ventilated paint shop in Malaysia. The thermal comfort was warm to hot, which increased with higher RH along with the radiant temperature in the presence of rain. While no substantive findings are recorded for the other variables, there was a reduction in lighting to 50 lux due to rain despite artificial lighting.

Lai *et al.* (2009: 930) evaluate IEQ acceptance in buildings in Hong Kong, which showed that the overall IEQ acceptance was affected by operative temperature, CO_2 concentration, equivalent noise level and illumination level. Based on Fanger's (1970) comfort equation, both thermal and acoustic environmental qualities were considered the most significant contributors, whereas IAQ was considered the least. The predicted overall IEQ acceptance was sensitive to an operative temperature higher than 28 °C, but not to the CO_2 concentration. A major drop in the approval was also found when the noise level exceeded 70 dBA, while the visual recognition increased steadily from an illumination level of 10 lux and remained relatively steady at 50 lux or above (Lai *et al.* 2009).

Wong *et al.* (2008: 1) examine IEQ variables of heat, IAQ, acoustics and lighting. The overall IEQ acceptance was computed from a multivariate logistic regression model. It is the intention of the present study to evaluate the IEQ in commercial kitchens using the model. At 24° C to 26° C, the predicted IEQ acceptance is above 80 % for an office of an average IEQ, but the acceptance will drop to below 40 % for an office having a bad environment. From the observation of the expected overall IEQ approval, 'good', 'average' and 'bad' levels of satisfaction are obtained. Both the studies, however, failed to discuss the impact of one variable over the other. Interrelationships between the dual variables, covariates, and multiple variables were not detected.

Cao *et al.* (2012: 394) measure IEQ variables including occupants' satisfaction regarding various environmental factors. For each variable, the association concerning occupants' satisfaction and the environmental parameter was established. The authors recommend that studies of IEQ and human comfort evaluation should consider the comprehensive influence parameters. However, interrelationships among variables were not analysed.

This study is similar to the current research with a comparable methodology that supports the equipment measurements with questionnaires, interview schedules and an observation checklist. The relationship between overall satisfaction and the environmental parameters was evaluated for human comfort, in the present study, with the consideration of multiple factors. Occupiers may feel dissatisfied with IEQ because one of the elements has an extreme value (Cao *et al.* 2012: 398).

Gauthier and Bourikas (2020: 323) study environmental discomfort, but the results showed no relationship between the parameters, although associations were drawn between physical environmental parameters and the stated comfort levels. Barthelmes *et al*. (2020: 321) study the combined effect of IEQ, interfaces between IEQ, and behavioural actions - occupant's characteristics, inclinations for adaptive actions, and the impact of behavioural actions on indoor settings. However, the results obtained are not discussed but provide a planned outline of a monitoring framework for open-plan offices.

Tharim *et al.* (2017: 323) survey an office building with 15 areas of assessment for IEQ. The study suggested that the IEQ variables contributed to occupant's satisfaction. Surprisingly, there is no significant relationship between acoustic comforts with occupant's satisfaction. It is necessary for building residents to score 80 % on satisfaction level, else a corrective action needs to be in place.

5.11.3 Interrelationship between IEQ variables and other parameters

The mention of prior studies indicate that similar interrelationships could be occurring in the commercial kitchen environments. Many indoor environmental stressors can cause effects additively or through complex interactions. These can be synergistic or antagonistic namely, draft and temperature; view and luminance ratios, odours, humidity, mould, radiation, chemical compounds, particulates; noise and vibration (Torresin *et al*. 2018: 525. Kim (2017: 280) critiques ASHRAE's performance measurement protocols (PMP) model and reports that it does not provide guidance on the inconsistencies in the results between the IEQ survey and spot evaluation of the same space when they arise. The following section will conduct an exploratory review on multiple IEQ variables.

5.11.3.1 Building features and design

Clements *et al*. (2019: 1) theorise that the building system design contributes significantly to spatial variability in air temperature, lighting and sound masking exposures. Environmental psychologists have documented the positive impact on well-being and functioning of building users of many design characteristics, such as reduced noise, enhanced lighting and ventilation, better ergonomic designs, supportive workplaces, the provision of personal control and improved layouts (Gifford and McCunn 2018: 111).

A summary of Frontczak and Wargocki (2011: 25) infers that workers placed relatively high importance to contributions coming from light, sun, temperature, fresh air and smell. The results showed that satisfaction with all 15 environmental parameters and building features listed in the CBE occupant satisfaction survey contributed significantly to overall satisfaction with personal workspace.

Building on the work of Frontczak and Wargocki (2011: 937) and others, Kim and de Dear (2012: 1) examined relationships between IEQ categories and overall workspace satisfaction. The authors used Kano's model of customer satisfaction to analyse IEQ category performance into more detailed relationships with satisfaction, such as basic factors, bonus factors and proportional factors. The basic factors in the Kano Model of satisfaction include temperature, noise level, amount of space, visual privacy, adjustability of furniture, colours and textures and workspace cleanliness (Kim and de Dear 2012: 1). Sethi and Malhan (2015: 71-73) endorse that workplace comfort is a basic need of kitchen staff in the kitchen and involves factors such as temperature and humidity, layout features, safety, hygiene and sanitation. In kitchens, providing adequate basic environmental factors including amount of space and workspace cleanliness is essential. Simone *et al.* (2013: 1001) emphasise that an acceptable thermal environment is provided for kitchen occupants.

Some proportional factors, such as IAQ, amount of light, visual comfort, ease of interaction, should be the purview of basic factors in kitchens. Sound privacy, comfort of furnishing, building sanitation and building maintenance are other proportional factors according to (Kim and de Dear 2012: 19).

Kim's (2012: 58) field test set out to evaluate the ASHRAE, CIBSE and USGBC's performance measurement protocols (PMP) for commercial buildings in Texas. It was found that ASHRAE PMP accomplished its goal of providing the standardised procedures for evaluating and comparing the overall performance of a building, including energy, water and IEQ. The author adds that several areas for improvement were identified such as conflicting results from different procedures, limited guidelines for performing the measurements; lack of graphical indices and clear benchmarks (Kim 2017: 281).

Park *et al.* (2018: 1) Post occupancy evaluation (POE) IEQ measurements of office buildings comprised of objective IEQ measurements along with subjective surveys with a significance analysis of thermal satisfaction. It was found that the level of thermostat control was related, significantly, to occupant satisfaction in both open-plan offices and closed offices. Although the bivariate analysis reveal the relationship between measured and perceived IEQ indices, interdependencies between IEQ indices, and other satisfaction variables of significance, it failed to perform multivariate analysis between IEQ parameters. The study also claimed to explore correlations between occupant satisfaction and measured data with an integrated survey method. In parallel, this study will also explore interdependencies between IEQ parameters, with the addition of multivariate analysis between the IEQ indices to establish a correlation between the parameters and discomfort among food service workers.

In another multi-variate study, Jimoh (2017: xx) creates a mathematical model based on objective data with IEQ sub-divided into its constituent parts. The researcher created a model based on objective data with IEQ as a composite. Treating IEQ as a single unit of analysis, which consists of five parameters seems accurate. The effect of covariates as in the lecturers' characteristics such as age and gender on IEQ parameters is accepted. Statistically significant differences in satisfaction with IEQ is revealed with regard to gender differences (Jimoh 2017: xx). However, on the age factor, a significant difference in satisfaction with acoustics is achieved. This study advances the well-being of occupants, and interrelationships assessment to improve work performance.

There is a dearth of research on such combined studies. Jimoh (2017: 139) laments that the lack of thresholds or standards on IEQ parameters in Nigeria could be responsible for this outcome. However, a study by Yang and Moon (2019: 628) finds that an illuminance level of 500 lux was preferred for visual comfort, thermal comfort, and indoor environmental comfort; however, their statistical significance was not confirmed except for thermal comfort. In this regard, the researcher also observes that there are no IEQ parameters for commercial kitchens in SA.

Heinzerling's *et al.* (2013: 13) evaluation of the performance measurement protocol**s** (PMP) provides an accurate comparison of IEQ performance of commercial buildings (ASHRAE/CIBSE/USGBC 2010: 6). The authors' allocation of weighting of the IEQ categories when determining overall IEQ quality provides a factor of relative importance based on an occupant survey. The results are determined through regression coefficients. The researcher will also perform a similar statistical analysis to establish relationships among various elements across different data-gathering tools. The REHVA Indoor Climate Quality Assessment (ICQ) guidebook represents a good first attempt at outlining the issues of IEQ evaluation. Such measurements implemented in standardised fashion can transform the measurements of IEQ models into scores that can be used in ratings and standards.

Dawe's (2019: 2) post-occupancy assessment on IEQ with occupant surveys in eight LEED-certified buildings find that none of the buildings achieved an 80 % thermal satisfaction rate, which is defined as people expressing satisfaction from +1 to +3 with the heat. The author also adds that acoustics had low satisfaction across all eight buildings, and most concerns arise from sound privacy in open-plan offices.

Gifford and McCunn (2018: 106) posit that attempts to design buildings to approaches comprise social design and evidence-based design. Designing buildings to best serve human needs and wants, for example, restaurants and coffee shops have social designs typical for their functional use. The authors lament that a gap often exists between building designers and building users; favouring a human-oriented, democratic approach within the local context can help ensure that the design will enhance well-being and health-promoting behaviour.

5.11.3.2 Particulate matter

Chiang *et al.* (2001: 561) quantitatively assess eight variables such as sound level pressure, CO_2, illuminance, airspeed, air temperature, RH, as well as CO_2 and PM 10 in airborne dust in the physical environment of a care centre for aged people in Taiwan. The measured score of the physical factors showed a high degree of agreement and positive association with the mental response of aged from the questionnaire. The authors further report that POE procedure revealed that two factors, noise levels > 46 dB(A) and RH < 37 %, are determined as the important and adverse factors in the winter season.

Later, Chiang and Lai's (2002: 387) study of indoor environment assessment for occupants' health in Taiwan included measurement of Formaldehyde (HCHO), Volatile organic compounds (VOCs) for IAQ, electromagnetic fields, water quality and greens besides IEQ. The authors followed the analytic hierarchy process method and an indoor environment index (IEI). Both the studies, however, failed to discuss the impact of one variable over the other. The interrelationships between the dual variables, covariates, and multiple variables were not detected.

5.11.3.3 Transiency occupancy

Transient occupancy occurs as per Berquist *et al*. (2019: 89) during transient environmental interactions such as in a mall. As transient occupancy may to a limited extent occur in split shifts among kitchen workers, the variable is not a part of this study.

5.11.3.4 Demographics

Jimoh (2017: xx) investigates IEQ variables such as temperature, RH, ventilation, noise, lighting and workspace utilisation in university buildings. The investigation reveals that gender and age of lecturers affect their satisfaction with IEQ parameters such as acoustics, while workspace characteristics such as type of building, floor level, direction faced by the window, and type of office affect their contentment with IEQ parameters like size of workspace, ventilation and visual comfort. Park *et al*. (2018: 1) concurs in a study of office buildings and report that there is a significant difference between men and women in thermal dissatisfaction. This difference between the genders may be due to clothing insulation and metabolic differences. The current study will explore the significance of gender and age on the different IEQ factors among kitchen workers.

5.11.3.5 Personal control

Huizenga *et al*. (2006: 393) claim that IAQ and thermal comfort are two important aspects of indoor environmental quality that receive considerable attention by building designers. The authors recommend providing thermostat or operable window control to more occupants as the means of achieving higher occupant satisfaction. This is also recommended by Boyce *et al*. (2006: 213) who claims that that personal control leads to beneficial outcomes as people respond favourably to having such control; the state of perceived control is desirable (Gifford and McCunn 2018: 111).

In support, Dawe (2019: 2) reports that the primary factor leading to heat discomfort in these buildings is lack of control over the thermal environment, both for heat and airflow. The adjustability of furniture and airflow control among university lecturers affect their contentment with IEQ parameters (Jimoh 2017: xx).

Frontczak *et al.* (2012: 56) add that the indoor environment is to a large extent controlled manually by the building users, for example, by opening the windows to regulate ventilation or setting the thermostat levels to regulate heating. The current study will explore the element of control in kitchens where access to switch on light bulbs and adjust thermostatic controls, ventilating equipment and fans provide satisfaction to kitchen workers.

The researcher proposes that features to resolve the comfort issues are fast-response behavioural changes such as opening windows and operate fans that allow for individual control of environmental conditions. To monitor and measure combined IEQ, a low-cost suite of sensors integrated and data-processing capabilities autonomously measure key IEQ indicators (Parkinson *et al.* 2020: 13). These measures can improve building performance and IEQ and occupant satisfaction, health, well-being and performance.

5.12 Limitation of prior IEQ investigations

Bluyssen (2019: 2) criticises the assessment of dose-related indicators of IEQ, based on single dose-response relationships as developed for the average occupant. Such measures ignore the fact that individuals are in different scenarios such as homes, offices and schools, and different situations such as washing and cooking. It seems that dosage exposure and response may depend on time and other variables such as physical, physiological, personal, psychological and social needs that are all taken into account, not per variable, but integrated. Methodological protocols are consequently raised. Bluyssen (2019: 2) adds that the selected approach must be suitable for determining patterns of stressors and interactions and takes account of dynamic behaviour over time per scenario. Sujanova *et al*. (2019: 22) however, endorse the need to shift the emphasis from physical parameters to evaluate the IEQ performance and prove that other performance parameters such as type of space, building design, and working conditions have a bearing on the overall satisfaction of occupants with the building environment.

IEQ may be moderated by uncontrollable external factors such as seasons (Kim 2012: 357), topographical areas and building construction as Sakellaris *et al*. (2016: 12) reported because of the discrepancies in variables. For example, the relation between light and overall comfort was higher in Southern Europe compared to Central/North Europe. This difference may be explained by different climate conditions, as well as differences in building structures. Conversely, the relation between air quality and comfort was higher in Northern and Central European offices (Sakellaris *et al*. 2016: 8).

The relationship between IEQ and well-being is complicated. Table 5.5 (112) lists the studies on kitchens and the IEQ parameters measured across different geograpgical areas with dissimilar climatic conditions. Only two studies measured acoustics and lighting along with other IEQ, however no relationships were correlated.

Being already under significant stress due to peak periods, food-service workers are likely to be more affected by indoor environmental design flaws and in addition, each worker may have different environmental needs due to variation in ethnicity and adaptation that has received very little attention in environmental design research.

Table 5.5 Summary of studies on IEQ in kitchens (By researcher)

Source	Location of kitchens	Temp	RH	Air flow	CO_2	Noise	Light	Work space	Type of kitchen/ equipment	Architectural features	Personal factors*	Secondary factors**	Phenotype and genotype***	Comfort/ discomfort
		Thermal Comfort												
Heinonen (1997)	Various food services	√	√	√					√					
Akbar-Khanzadeh *et al.* (2002)	Restaurants	√	√	√	√									
Eagles and Stedmon (2004)	U.K Restaurant	√	√	√		√	√	√						
Kajtar *et al*. (2005)	Building	√	√	√	√				√					√
Haruyama *et al*. (2010)	Various food services	√	√	√					√	√	√	√		√
Matsuzuki *et al*. (2011)	Various food services	√	√	√				√	√		√			
Saha *et al*. (2012)	Student hostels	√	√	√	√				√					
Zhao *et al.* (2013)	Chinese Restaurant	√	√	√	√									
Simone *et al.* (2013) No discussion	US Restaurants	√	√	√	√			√		√	√	√		√
Zhao *et al.* (2014)	Chinese kitchen	√	√	√	√									
Hima Bindu and Reddy (2016)	Various food services	√	√	√	√	√	√							√
Singh *et al.* (2016)	Commercial kitchen	√	√	√	√						√	√		√
Beheshti *et al.* (2015)	Bakeries	√	√	√										
Rahmillah *et al.* (2017)	Domestic kitchens	√	√	√										√
Sajedifar *et al.* (2017)	Hospital kitchen	√	√	√							√			√
Logeswari and Mrunalini (2017)	Student hostel	√	√								√			
Alam *et al*. (2019)	Railway pantry cars	√	√	√							√	√		√

Personal factors*-age, gender, race, height, weight, BMI

Secondary factors**- work experience, work shift, job position, work activity, physical fitness and health status

Phenotype and genotype***- hair, skin colour, type of nose, body type

5.13 Conclusion

The lighting levels vary widely across kitchens and the lighting standards also differ broadly across different countries. The interrelationship between various parameters is shown in this chapter to vary widely, depending upon several factors such as geographic location, climate, type of building and presence of fenestrations. The influence of five parameters of environmental quality is not necessarily clear-cut. Although all the parameters are significant, this discussion does find that for the well-being of kitchen workers in commercial kitchens, heat by and large plays an important role. The next chapter will discuss the methodology of the study. Table 5.5 compares the various studies by researchers on kitchen IEQ and indicates that various primary and secondary variables were excluded and or not discussed.

CHAPTER SIX

METHODOLOGY

6.1 Introduction

This chapter offers a detailed explanation of the research strategy employed to meet the aims and objectives of this study. The initial sections of this chapter will outline the research questions of the study and then proceed to discuss the selected case studies.

6.2 Research questions

The following research questions had been set to help address the aim of this study.

1. What is the level of indoor airflow, humidity, the thermal environment, lighting and acoustics in restaurant kitchens?

2. How does heat stress affect food production workers who use gas and kitchen appliances?

3. What are the perceptions on the adaptability of food production workers to selected indoor environmental conditions?

4. What indoor environmental criteria is required to design restaurant kitchens in Durban?

6.3 Research design

Numerous authors have remarked on the merit of effective research design. Flick (2019: 98) asserts research design as a plan to answer a research question. According to Sekaran and Bougie (2013: 95), a research design is an outline for the collection, measurement, and analysis of data based on the research questions of the study. Additionally, Bryman and Bell (2011: 41) state that research design provides a context for the collection and analysis of data. Integral to research design is the purpose of the study, the research strategy, its location, the extent to which the study is manipulated and controlled by the researcher, its time horizon, and the level at which data is analysed (Sekaran and Bougie 2013: 95).

Tight (2017: 22) describes a case study as a research design that is less concerned with establishing causal connections, or generalisation; it focuses on understanding behaviour in its specific social context. The research design utilised in this study incorporated a non-experimental, exploratory, case study design.

6.3.1 Exploratory design

Following Flick (2019: 99) the exploratory research design used in this study is aimed at determining the occurrence of events in a certain field, context or situation.

Accordingly, the present study followed a systematic and scientific approach to extend available knowledge in IEQ. This study embarked on exploratory research per University of Southern California (2019: 10) with the objective of exploring an area where little is known. There are few or no earlier studies to predict an outcome or, to investigate the possibilities of undertaking this study. This type of design is often used to establish an understanding of how best to proceed in studying an issue or what methodology would effectively apply to gather information about an issue. These assertions also accord with that of Sekaran and Bougie's (2003: 96) explanation of exploratory studies that point to its necessity when some facts are known, but more information is needed for developing a viable theoretical framework. Moreover, Kapur (2018: 26) claims that exploratory studies focus on the subject matter with no hypothesis being formulated. Against this backdrop, the current study used an exploratory research design to examine IEQ in commercial kitchens.

6.3.2 Research Approach

A mixed method approach was considered appropriate for this study. Gauthier and Bourikas (2020: 325) applied a mixed method approach to study the effect of environmental parameters on discomfort. Clark and Ivankova (2016: 59) define mixed methods research as a process of research when researchers integrate qualitative and quantitative methods of data collection and analysis to understand and address a research problem. Bryman (2006: 8) states that the criterion for qualitative and quantitative components of mixed methods comprise of "mutually illuminating" and collaborative effects of eliciting facts. Flick (2019: 29) accordingly claims that mixed methodology approaches are interesting for their value on combining qualitative and quantitative research. The simplest way of making the distinction between these two approaches is that qualitative research uses words and quantitative research uses numbers which when combined are a major strength (Maxwell 2018: 7). The key difference between quantitative and qualitative methods is their flexibility, with argument that quantitative methods are fairly inflexible (Sharifirad 2016: 2). It seems that quantitative techniques call for many rules and procedures to ensure the rigour of their results.

Morgan (2018: 274) requests for leveraging the strengths of the two methodologies in mixed methods research. Fetters *et al.* (2013: 2134) considers mixed methods research as a novel third methodology and these methods add value when integrated. The exploratory approach adopted in this study for these reasons, used mixed methods for its feasibility to benefit the findings of this study.

The present study, however, leans toward quantitative techniques to obtain data. Quantitative data collection was combined with some qualitative techniques. The purpose of the quantitative data was to evaluate objective data whilst the qualitative data per Creswell (2013: 69), was obtained from respondents. The qualitative methodology utilised in this study adapted from Hignett and Wilson (2004: 473) for ergonomic practice in restaurant kitchens.

6.3.3 Data collection instruments

The research instruments used in this study comprised of a questionnaire, interview schedule, and structured observations. The instrument design, population size, sample techniques, and instrument distribution are explained in detail in section 6.4.2 and are summarised below in Table 6.1.

Table 6.1 Summary of methodological choice for the study (by researcher)

Unit of analysis	Instrument	Population size	Sample technique	Sample size	Instrument and administration
Commercial Kitchens	Observation checklist	1563 eThekwini Municipality	Purposive sampling	33 Case studies	Gauge
Head chefs and kitchen managers	Self- administered Questionnaire	40	Purposive sampling	33	Self-administered
Food service workers	Interview schedule	510	Purposive sampling	170	Face to face

6.4 Research strategy

A research strategy is a step-by-step plan of action that gives direction to the researcher's opinions and determinations, facilitating researchers to conduct investigation scientifically and on schedule to produce quality results and detailed reporting (Dinnen 2014:1). Research strategy according to Bryman and Bell (2011: 26) is a general orientation to conduct research. Of relevance to the present study, Datt and Chetty (2016:2) claim that research strategies based on a mixed approach include a case study. It may involve a single study or multiple studies (Creswell and Clark 2013: 174). The current study is a multiple case or collective case study explained in 6.4.1.

6.4.1 Case study design

According to Trochim *et al.* (2016: 9), a case study is a small-scale research with meaning. Flick (2019: 107), adds that the aim of a case study is the precise description of cases; the main problem is to identify a case that is significant for the research question and what methodological approaches its reconstruction requires. A case study is often used to narrow down a very broad field of research into one or a few easily researchable examples (University of Southern California 2019: 4). According to Yin (2014: 4), the case study method is relevant when research requires an extensive and “in-depth” description of phenomena.

The case study's unique strength is its ability to deal with a full variety of evidence-documents, artefacts, interviews and observations (Yin 2009: 11). The author adds that a case study has a distinct advantage when a "how" or "why" question is being asked about a current set of events over which the investigator has little or no control. Appropriate to the present study, Rule and John (2015: 4) declare that a case study is an empirical analysis that examines a present phenomenon within its real-life context, especially when the boundaries between the phenomenon and context are not apparent. If the case study contains a rich presentation of evidence in tables and figures, the case is more reliable (Gustafsson 2017: 5).

The difference between a single case study and a multiple case study is that the researcher is studying multiple cases to understand the differences and the similarities between the cases (Baxter and Jack 2008: 550). However, Vannoni (2015: 2) claims that the multiple-case designs have distinct advantages and disadvantages in contrast with single-case designs. Relevant to the current study, the evidence from multiple cases is known to be more compelling, and the overall study is regarded as being more robust (Yin 2003: 45). It also potentially offers both quantitative and qualitative data for analysis and interpretation (Sekaran and Bougie 2013: 241). However, the conduct of a multiple-case study may require extensive resources as experienced in the current study that was time consuming, exhausting and required demanding logistical and probing tactics.

The evidence created from a multiple case study hence is strong and consistent (Baxter and Jack 2008: 550). Other advantages with multiple case studies are that they construct a more convincing theory when ideas are deeply grounded in several empirical evidence. Thus, multiple cases permit wider exploring of research questions and theoretical evolution (Eisenhardt and Graebner 2007: 25).

In replication logic, according to Ridder (2017: 60), constructs and propositions can be refined across the cases. Following Yin (2014: 60) the researcher selected the cases carefully to enable prediction of similar results across cases or divergent results based on theory. Hence, kitchens with comparable equipment that reflected kitchen loads were grouped to make comparative inferences from observed data and explore differences within and between cases.

6.4.2 Important concepts applied in the current study

6.4.2.1 Population

Sekaran and Bougie (2013: 240) explain that population refers to the entire group of people, events, or things of concern that the researcher needs to explore. Since there is rarely enough time or money to gather information from everyone or everything in a population, the goal is to choose a representative sample of that population. It is a complete set of elements: persons or objects that possess some common characteristic defined by the sampling criteria established by the researcher (Omair 2014: 142). The population here includes all the food service establishment kitchens in Durban.

6.4.2.2 Population frame

A population frame is the source material from which a sample is chosen. It is a list of all those within a population who can be sampled and may include persons, homes or organizations (Villamayor 2015:1). The population frame for the study comprised of eThekwini Municipality licensed restaurant kitchens. A list of restaurants currently operating in eThekwini Municipality was compiled from the Tourism Board SA (2015: 1) after cross-referencing against the list of licensed restaurants. Consistent with Frazer (2012: 365), only food service operations with a minimum of ten staff were considered as restaurants and were included in the study. In keeping with the study of Simone *et al.* (2013: 1002), commercial kitchens attached to casual dining restaurants, franchised operations, fine dining restaurants and coffee shops that granted permission for the study formed the population frame.

6.4.2.3 Sampling frame

Every element in a sampling population should be individually identified to have a sampling frame for that study population (Kumar 2015: 178). A list identifying each unit in the study population is called the sampling frame (Swisher 2017: 1**).** The sample frame consisted of kitchens serving different cuisine and having different styles of service were selected. Cognate studies have similar sample frames. According to Sharma *et al.* (2009: 59) selecting just ten restaurants can maximise the diversity of establishments studied. Rajasekar and Ramachandriah (2010: 6) chose thirty representative houses to study adaptive comfort and thermal expectations for a subjective evaluation in a hot humid climate.

Haruyama *et al.* (2010: 137) evaluated subjective thermal strain in ten kitchens using subjective judgement scales (SJS). Matsuzuki *et al*. (2011: 605) reported a study on commercial kitchens that involved sixteen workers that adopted a sample frame of eight kitchens. The sampling frame for this study consisted of 33 restaurant kitchens in the Durban area.

6.4.2.4 Sample

A sample is a subset of the population (Sekaran and Bougie 2013: 241). In this study, it comprised of some food production workers and kitchen managers from the selected restaurant kitchens. A complete enumeration of each population comprising of food production workers and kitchen managers was not possible as all staff were not present at their stations in the time slots when permission for data collection was granted. Thus, the population consisted of 170 food production workers on duty for that specific shift on that particular day in restaurant kitchens, 33 kitchen managers or head chefs. The unit of analysis was the selected commercial kitchens.

6.4.2.5 Development of instruments

According to Kumar (2015: 1), the first step in tool development is a careful examination of the extant theory which is currently or actually existing theory relating to the construct the researcher decides to measure. In social research, there are three main forms of data collection namely, questionnaire, interviews and observation or studying documents. Since every method has its limitation, it is useful to combine methods (Flick 2015: 129). In this study, multiple forms of data collection were undertaken. The researcher developed the instruments from the construct and latent variable that were formulated.

A latent variable model, as the name suggests, is a statistical model that contains unobserved variables (Cai 2012: 188). The theoretical basis for the construct was defined and the relationships it had with other constructs was predicted. In addition, the researcher revisited the research questions frequently to ensure that the generated items reflected the dimensions and elements of interest and remained relevant. These dimensions are heat, ventilation and humidity, noise and lighting. At this stage, the proposed subscales of the tool were identified and verification of the representativeness of items was undertaken. The item and factor analysis stages of the tool development process were used to establish whether such items were representative of the expected factor.

The type of tool, language used, and order of items may bias responses according to Kumar (2011: 39). Consideration, therefore, was given in questionnaire and intervies to the order in which items were presented and controversial items were avoided at the beginning of the tool. Double barrel and double negative questions were avoided. A mixture of both positively and negatively worded items minimised the danger of interviews and acquiescent response bias, that is, the tendency for respondents to agree with a statement or respond in the same way to items. Test equipment was selected on their ability to observe and measure variables.

6.4.2.6 Self-administered questionnaire

A questionnaire is commonly a set of printed or written questions with a choice of answers and is devised for a survey or statistical study. Consistent with Veal (2011: 127), a questionnaires were used to gather qualitative as well as quantitative data by the inclusion of open-ended questions (Appendix 3a). Studies of similar variables of interest have adopted self-administered questionnaires for data collection. Simone and Olesan (2013: 5) however, used two questionnaires, one on long- term effects and one on occupant-kitchen workers' immediate reaction on thermal working conditions. Matsuzuki *et al.* (2013: 171) used self-administered questionnaires to assess job-related stress among hospital kitchen workers addressing key variables. Debois (2019:1) states that every questionnaire is a survey, but not every survey is a questionnaire.

The literature revealed significant and relevant measures of interest. In particular, the publications of Payne-Palacio and Theis (2016), Thomas *et al*. (2013), Sethi and Malhan (2015) and Gregoire (2017) provided details for instrument development in respect of kitchen layout and planning. The final questionnaire consisted of both closed and open-ended questions in English. Every effort was made to measure the relevant dimensions, variables and elements without repetition. The questionnaire intended for the head chefs or kitchen managers consisted of 43 main questions. The first section comprised of basic demographic information on the food service workers and background information about their experience, current position, the type of enterprise, cuisine, menu, covers, occupancy, number of meals cooked and busy periods.

The second part elicited data on their perceptions about the various parameters such as heat, humidity, air velocity, lighting and noise that were later measured with test equipment. The questions also prompted information on their insight about staff responses to the kitchen environment on heat, humidity, airflow or ventilation, noise and light.

Almost all the questions were close-ended except for a question on noise. There were 19 closed-ended questions on heat, 11 on illumination, 17 on noise, and 22 on ventilation and humidity. The Likert scale was used for 25 closed questions requiring quantitative responses. The measurement scale for data was ordinal, but the variable was treated as continuous. For example, a Likert scale that contains five values - strongly agree, agree, neither agree nor disagree, disagree, and strongly disagree is ordinal. The questionnaire had 19 nominal items, 10 ordinal items, 12 ratio items and 2 interval scale items. Fifty-five items were chosen for Objective 1, twenty-four for Objective 2 one for Objective 3.

6.4.2.7 Interview schedule

Yin (2014: 103) emphasises that interviews are one of the most important sources of qualitative data collection. An interview is a method of collecting verbal data and is a systematic form of asking people questions for research purposes (Flick 2015: 142, 267). This method makes knowledge about practice and process accessible. Hence, the use of this instrument was necessary to elicit information on the reactions of food service workers to the kitchen environment (Appendix 3b)**.** Ridder (2017: 381) asserts that an interview is an intervention into the life of a participant, and by means of shared communication, it is possible to discover the social order under exploration. An interview schedule is a written list of questions, open-ended or closed-ended, prepared for use by an interviewer in a person-to-person interaction (Kumar 2011: 37).

A structured interview provides uniform information, which convinces the comparability of data. Semi-structured interviews prompt the interviewed subjects' perceptions expressed in an openly designed interview situation compared to a standardised interview (Flick 2019: 216). The interview schedule for the current study included established themes from the seven-point thermal scale of Simone and Olesan (2013: 1006). Studies of similar variables of interest have adopted interviews for data collection. Parameswarappa and Narayana (2014: 861) interviewed workers to collect information on heat stress in a steel industry and Cann *et al*. (2008: 222) used semi-structured interviews to gather information on workplace risk in the food service industry.

The interview schedule intended for the food service workers consisted of two sections. The first section comprises 39 questions on basic demographic information on the food service workers and background information about their age, gender, race, experience, shift, current position, comfort with uniform, makeup, hairstyles, fitness levels, personal habits, weather, skin colour and type of nose.

The second part is adapted from the work of Kim *et al.* (2013: 247) and focused on respondents' opinions on heat, ventilation, humidity, lighting, noise and space design. The interview schedule comprised of a series of open-ended questions according to themes. The researcher retrieved information on the socio-economic background of workers, adaptability and the specific tasks performed. The scales used comprised of nominal items (86 %), ordinal items (12 %) nominal and ratio items (0.014 %). Twenty-two items pertained to Objective 1, twenty-six items to Objective 2 and eleven and six items to Objectives 3 and 4 respectively.

6.4.2.8 Observation schedule

Observation is a purposeful, systematic and selective way of watching and listening to an interaction or phenomenon as it takes place (Kumar 2011: 134). These according to the author are appropriate in situations in which observations are the most appropriate method of data collection when a respondent is unable to provide objective information. He further explains that non-participant observation researchers do not get involved in the activities of the group but remain passive observers, watching and listening to the activities and drawing conclusions. Less formal direct observation is an important source of evidence in case study research as this takes place in the real-world setting of the case (Yin 2014: 113). Naturalistic observation is a method of research that is often used by social scientists and is a technique involving the observation of subjects while they remained in their natural environment (Ayres 2019: 1).

Observation can be so valuable that taking photographs increases the reliability of observation. Heinzerling *et al.* (2013: 32) took photographs of equipment and buildings in the study of IEQ. The planned observation for this study was structured. It is notable that Tornstrom *et al.* (2008: 220) collected information for an ergonomic assessment model using interviews, questionnaires and observation. In addition, the layout of kitchens captured by still photography.

Food services literature was studied at length to frame the checklist per Palacio and Theis (2009); Sethi and Malhan (2015) and Gregoire (2017). A code of practice, a checklist on ventilation by Honeywell (2017: 1) and a checklist on lighting by ILO (2017) were adapted to measure parameters relevant to the research topic. There were 49 nominal items and 38 ordinal items of which 34 were Likert scale and eight ratio items (Appendix 3c). More detail on observations is given in the data-gathering section.

The structured observation schedule was the primary tool used to collect data from 33 restaurant kitchens in Durban. The research instrument consisted of 103 items, with nominal and ordinal measurements. The observation schedule was divided into 9 sections, which measured various themes as illustrated below:

Section AA – Structural design and material

Section AB – Facility design, layout and lighting

Section BA – Thermal environment

Section BB– Noise in kitchen

Section BC – Dishwashing

Section BD - Ventilation

Section BF - Facilities adjustment and cleaning

Section CB - Pest control

Section DA- Measurement of environmental ergonomic parameters

6.4.2.9 Test equipment for measurement

Rajasekar and Ramachandraiah (2010), Matsuzuki *et al.* (2013), Simone *et al.* (2013), Nassiri *et al.* (2013) and Akbari *et al.* (2013) have found success in the use of one or more of these measures in their studies. Direct measurement involves a measurement output from a device such as a light meter for measuring illumination (Dempsey *et al*. 2005: 489). Clements *et al*. (2019: 12) measured flow rates through spot checks of air velocity to evaluate IEQ. Park *et al* (2018: 4) evaluated IEQ of offices by SM of thermal, air, visual and acoustic conditions. Krishnamurthy *et al*. (2017: 101) used spot readings of WBGT for a steel factory at Salem in India. Tartarini *et al*. (2018: 57) assessed the thermal environment of a nursing home by SM of indoor air temperatures. Simone *et al*. (2013: 1004) adopted short-term or SM for globe temperature, air temperature, operative and radiant temperatures as well as air velocity and RH in commercial kitchens. Similar processes were followed by Simone *et al*. (2013: 1003) when measuring and recording thermal parameters in different types of kitchens.

Using online searches, the researcher acquired equipment that met the validity and reliability specifications for the primary study. The selected equipment (Table 6.4 page128) accords with the South African Bureau of Standards (SABS) which provides a range of standards covering the demands of the calibration industry and helps the organisation enhance customer satisfaction, meet regulatory, safety and reliability requirements to ensure consistency of quality throughout the supply chain (Cole-Parmer Scientific Experts 2018: 1). According to the National Regulator for Compulsory Specifications (2018: 1), all laboratories are accredited to SANS 17025 that provides the requirements for the competence for testing and calibration in laboratories by the South African National Accreditation System (SANAS). Calibration is performed on-site or under controlled laboratory conditions. Calibrated gauges for measurement of parameters assures validity and reliability of data collected.

6.5 Data collection

As can be gathered from 6.2, this study adopted multi-method research, in which quantitative and qualitative methods of data collection were combined. Firstly, according to Bryman (2003: 1142), to provide a more complete set of findings and secondly, to maximise the advantage of each and mitigate their weaknesses (Trochim *et al.* 2016: 70). Goertz (2016: 4) adds that multimethod work involves cross-case causal inference and within-case causal mechanism analysis and inference. The quantitative and qualitative technique for the study is itemised in Table 6.2.

6.5.1 Sampling method

Flick (2019: 108) claims that in case studies, sampling is purposive which focuses on concrete cases that can contribute to the knowledge in the study. Trochim *et al.* (2016: 87) also argues that in purposive sampling, the researcher samples with a purpose related to the kind of participant they need, usually seeking one or more specific kind of people or groups. These perspectives per Creswell and Clark (2011: 415) are simplified as an intentional selection of participants who have experienced the key concept explored. The purposive sampling of restaurants for this study is accordingly informed.

Table 6.2 Types of Quantitative and Qualitative data sources (by researcher)

Quantitative	Qualitative
• Quantitative data collection – Scientific equipment – Observational checklists – Questionnaire • Quantitative data analysis Used numeric data for: • description • comparing groups • relating variables	• Qualitative data collection – Semi-structured Interviews – Observations – Documents – Audio-visual materials such as photographs • Qualitative data analysis Used text and image data: • coding • theme development • relating themes

Kitchens were selected with due consideration to the type of cuisine to include diversity in cooking methods and a minimum of ten employees. The respondents were key informers as they experience the IEQ in kitchens during work. All the restaurants in the sample frame that were convenient in terms of operating hours and distance were requested to participate in the study. Purposive sampling was adopted to maximise what could be researched in the time available.

Charan and Biswas (2013: 121-126) contend that the method of sample size calculation is different for different study designs and one blanket formula for sample size calculations cannot be used for all studies. Any application of sampling logic to case studies would therefore be misplaced. Yin (2003: 51) posits that due to the nature of the case study approach, "the typical criteria regarding sample size are irrelevant". When cases are studied, a small number such as four to ten is used. The sample size must, however, relate to the question and the type of qualitative research. Kumar (2015: 330) accordingly, claims that it is an approach in which a few carefully selected cases are intensively studied. Bearing this in mind, the sample size selected consisted of 170 food production workers and 33 kitchen managers and head chefs from 33 different restaurants.

The extensive use of screening criteria in replication sampling logic according to Swisher (2017: 11) reduces the variance in the sample on purpose and hence is superior to sampling logic. Yin (2009: 54) further adds that multiple cases resemble multiple experiments and, the need is for replication logic, not sampling logic, for multiple-case studies. That means that each case must be selected carefully so that it forecasts comparable or an accurate replication or predicts dissimilar results but for anticipatable reasons or a hypothetical replication. The author adds that the capacity to conduct 6 or 10 case studies, arranged effectively within a multiple-case design, is equivalent to the ability to conduct 6 to 10 experiments on related topics. A few cases 2 or 3 would be literal replications, whereas a few other cases 4 to 6 might be designed to pursue two different patterns of theoretical replications. For the present study, a non-probability census sample was drawn from food service establishment workers who reported for duty during the data collection period. A census sample minimises sample bias (Kothari 2009).

6.5.2 Instrument administration

The current study followed the criteria per Kim and Haberl (2018: 60) that included a data collection protocol during walk-in measurements at peak times of business on-site for a day. The first step in conducting the field study was to approach each restaurant individually and recruit the owner or manager to participate in the research study. Next, 'gatekeeper' letters were obtained to conduct the study and dates were confirmed for evaluation of IEQ in the commercial kitchens.

Questionnaire administration involved early notice to the restaurants about the researcher's arrival. The managers or owners informed kitchen workers about the research two days prior to data collection. Head chefs filled in questionnaires in their kitchens or offices. The study setting was non-contrived as it was conducted in a natural setting. Sekaran and Bougie (2016: 99) state that the extent of interference by the researcher has a direct bearing on whether the study undertaken is correlational or causal.

According to Haberl *et al.* (2008: 6-8) in Level 1, information about the thermal comfort of buildings relies on occupant surveys and spot measurements of ambient temperature (Ta), relative humidity (RH), mean radiant temperature (MRT) and air velocity (V air), that can then be compared to benchmarks such as those published by the CBE. Protocols for measuring IAQ at Level 1, as recommended, requires a hand-held meter to capture spot measurements -Ta, RH, CO_2 and CO. A heat index or WBGT meter was used to measure Ta, RH, WBGT and BGT. A hygrometer was used to cross check Ta and RH. An air quality monitor was used to measure CO_2 and O_2 levels. Air velocity was measured by an anemometer or ir velocity meter. V air, RH and CO_2 levels indicate ventilation in kitchens. The performance metrics required of selected IEQ parameters included temperature, humidity, mean radiant temperature, airspeed, CO_2; and measurements of illuminance and background noise (Kim 2012: 69). However, the author critiques ASHRAE's performance measurement protocols (PMP) because it lacks specific step-by-step measurement protocols that can be used for IEQ spot measurements.

Protocols for the performance measurement of lighting and daylighting rely heavily on standards published by the Illuminating Engineering Society (IES) (Haberl *et al.* 2008:7)**.** In Level 1, the basic method, occupant surveys and spot illuminance are made and compared to published illumination levels in the IES Standards (Haberl *et al.* 2008:7). Protocols for the performance measurement of indoor acoustics for Level 1, basic method, include indoor and outdoor decibel spot measurements, which are compared to the appropriate noise criteria for the space being measured.

Kim and Haberl (2018: 60) are of the opinion that in addition to instrumental measurements, an occupant 'right-now' survey of thermal sensation, comfort, acceptability, and preference should be conducted concurrently.

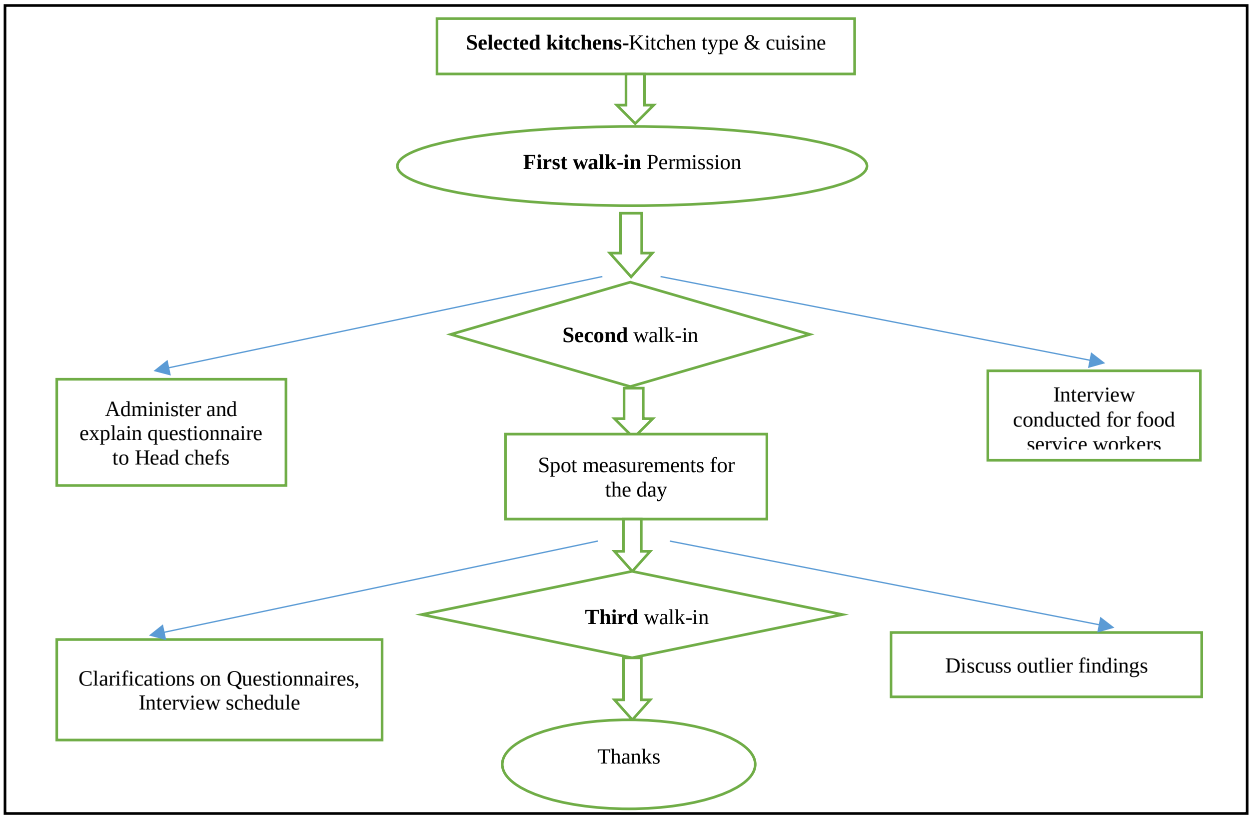


Figure 6.1 Scheme of instrument administration for data

Kumar *et al*. (2020:181) recommend that the collection of occupant satisfaction survey along with physical parameter measurement is the most effective way for IEQ assessment. As per the above recommendations, Level 1 measurements were taken in commercial kitchens, however, the criteria in kitchens are different from office requirements (Table 6.5 page 131).

The Level 2 protocol required data logging which could not be undertaken due to management fearing interference or being an obstacle in the kitchen. Kitchens are busy working places, and a data logging table occupies space and needs electrical cords that would obstruct kitchen workers when data is recorded. Berquist *et al*. (2019: 88) recommend that to investigate the relationship between IEQ and occupant comfort in commercial buildings, longitudinal and simultaneous evaluations of both aspects should be conducted to ensure the variations in indoor conditions and occupant demographics.

Saha *et al*. (2012: 183), Li *et al*. (2012), Simone *et al*. (2013: 1007), Logeswari and Mrinalini (2017: 607) conducted thermal studies in kitchens. However, these studies did not include noise and lighting. As the commercial kitchen environment in Durban presents different conditions than the studies mentioned, a measuring procedure was established focusing in particular on the processes characterising the kitchen space. Employees facing high-energy appliances, such as grillers, tunnel pizza ovens, deep-fat fryers are exposed to higher radiant temperatures than employees working in preparation areas a few feet from the appliances (Simone *et al*. 2013: 1003).

Table 6.3 PMP objective measurement requirements for the IEQ

Level	Thermal Comfort	Indoor Air Quality	Lighting	Acoustics
Basic	Spot measurements of temperature, RH, mean radiant temperature, airspeed	Outside airflow rates at each outside air intake Spot measurements of temperature and humidity to characterize occupant perceptions of IAQ	Spot measurements of illuminance in selected spaces	Spot measurements of A-weighted sound pressure level (dBA) in occupied spaces

According to National Skills Development Corporation (2015: 1), a dishwasher in India works in hot, wet, humid and noisy environments for long periods. Workers in dishwashing areas are subject to very humid hot air, and therefore, to higher discomfort levels (Johnson *et al*. 2019: 7).

Matsuzuki *et al.* (2013: 605) claim that the thermal conditions of the working environment in commercial kitchens are primarily driven by radiant heat, humidity levels and airflow that directly impact the employees. Rusnock and Bush (2012: 109) report that the activities in the kitchen influence the noise levels. Jobtips (2020: 1) claim that noise varies from moderate to noisy as noise levels might change during the course of the day in a restaurant business. Tasks in kitchens influence the amount of lighting utilised (Yazıcıoğlu and Kanoglu 2016:35). Moreover, appliances, size and arrangement of the kitchen zones, number of employees, variable environmental conditions during business hours such as occupancy and type of meals ordered complicate further evaluation of the indoor thermal environment in kitchens (Simone *et al.* 2013: 1001). Based on standardised methods as discussed above, a procedure for collecting data for the physical environment and subjective reactions obtained through interviews in commercial kitchens is presented in this study.

The classification of kitchens is based on an International Mechanical Code (IMC) that uses kitchen load as a basis for categorisation. This will assist in comparing the IEQ in different types of kitchen.

Table 6.4 Classification of sampled kitchens based on equipment and fuel (by researcher)

Light-duty equipment	Medium-duty equipment	Heavy-duty equipment	Extra-heavy-duty equipment-using solid fuels
Kitchen 1,2	Kitchen 3, 4, 5, 6, 7	Kitchen 8, 9, 10, 11, 12, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 25, 26, 27, 28	Kitchen 29, 30, 31, 32, 33

The researcher postulates that since there is insufficient cataloguing of classification of kitchens, the International Code Council (2018) IMC ergonomic system of organisation of kitchens can be adapted to establishments based on the type of equipment. Currently, it seems that the clear-cut demarcation of service methods or types of service styles in food and beverage operations is not strictly followed as most establishments are embracing the concept of customer orientation and make changes gradually in their operations to encompass a happy meal experience.

6.5.3 Self-administered questionnaires

The briefings to food service managers and head chefs were conducted a day or two prior to the fieldwork. Participants were informed that the study could improve their kitchen environment and their contribution was very important. A three-day lag time helped the researcher to follow up on unfilled questionnaire items and seek clarification. Non-responsiveness of respondents was absent as total participation was noted.

6.5.4 Interviews

An interview schedule was administered to food production workers. Chan *et al.* (2016: 511) reported that workers in a hot environment such as catering need to be interviewed individually to elicit responses free from any group bias, be more comfortable, regardless of heat stress and respond to their environment. Majumdar (2016: 1145) reported that workers in a hot ceramic industry were also interviewed on-site.

The food service and kitchen managers briefed the staff on the research to obtain a high response rate. A follow up personal visit by the researcher ensured better cooperation among the participants. Each worker was approached individually while performing their work requesting for 10-15 minutes of their time to be interviewed at their convenience. The researcher then sat with them in the kitchen during their break time or sometimes in the restaurant for the interview. The workers were generally shy to express themselves at first but slowly talked confidently about their experience of working in the kitchen. The semi-structured interview, as scheduled, lasted between 10 to 15 minutes depending on the respondent’s delay in answering the questions. All the workers were approached or interviewed during the day shift at breakfast, brunch or lunch. In one restaurant the data was collected during the evening as the business only opened from 12:00 hours. Various areas within the kitchen workspace served as venues to record worker perception of the work environment; removing the worker to a more comfortable atmosphere for interviewing could have introduced biased responses.

6.5.5 Structured observation

The third data collection tool with respect to kitchen layout and ergonomic design for all kitchens was evaluated by non-participant observation. The observation checklist was completed in two phases: Phase I and Phase II. In Phase I, observation checklist was filled in by the researcher by observing the facilities, layout and equipment present. Questions AA 1 to CB 90 were direct observations by the researcher which also included reactions of food service workers in the kitchens. Photographs were taken (Appendix 28) to record the facilities in the commercial kitchens as it helps overcome the typically fleeting nature of observation (Basil 2011: 246).

Phase II involved measuring equipment for the completion of the structured observation checklist from questions DA 91 to DA103 using gauges; intended to provide objective measures of environmental ergonomic design data. Spot measurement was followed by several prior studies namely, Clements *et al*. (2019: 12), Park *et al* (2018: 4), Krishnamurthy *et al*. (2017: 101) Tartarini *et al*. (2018: 31) and Simone *et al*. (2013: 1004) for IEQ parameter measurements in commercial kitchens.

A strategy adopted by the South African Mines Occupational Hygiene Programme in their code of practice on thermal stress (Department of Minerals and Energy DME 2002: 16) details the mandatory requirements for an occupational health program specific to thermal stress. Adapting this code of practice, the researcher categorised the thermal environment and practised the following steps in relation to heat stress. The observation process in each sampled kitchesn was implemented as follows:

Step 1: The kitchen was sub-divided into eight activity zones (receiving area, preparation area, stove, oven, holding area, dishwashing area, corridor (entrance to kitchen) and other (griller and or fryer).

Step 2: The IEQ parameters that affected heat such as assessment of ambient air temperature, WBGT, black globe temperature (BGT), air velocity and humidity were measured followed by noise and lighting levels.

The measuring equipment yielded several types of measurement: external temperature, humidity, noise, indoor ambient temperature, operating temperature, RH, noise and lighting by the researcher. Nine different kitchen zones namely, receiving areas, food preparation, cooking equipment such as stoves, ovens, fryers, grillers, holding areas, dishwashing areas and corridors. These were considered to have different thermal, humidity, ventilation, noise and light conditions in the commercial kitchen.

The researcher recorded kitchen temperatures and RH at time intervals of 15 minutes. The heat stress meter was used for spot measurements (SM**)** of thermal parameters **-** air temperatures, wet bulb globe temperatures and black globe temperatures at one foot off the working station where kitchen workers were working at a height of 1.5 m. It was not conducive to measure these parameters at different heights during the peak operating hours of one working day, as the kitchen was busy and the researcher was requested to refrain from undertaking this exercise. This restriction compounded the collection of detailed data.

The air velocity meter was used to measure the airflow and RH in different areas of the kitchen. The air quality monitor measured the CO2 levels (ppm) and O2 levels in percentage. The light meter was used to measure lighting levels in lux at a height of 1.5 m. Sound levels were measured by a noise level meter in dBA at 3-second intervals. The kitchen area was calculated from measured length and width with a laser measure (m). Hubbard (2020: 1) claims that architects measure distance with laser tools that are typically accurate to 1/16" and give an instant measurement with the touch of a button.

Table 6.5 provides a detailed list of equipment that was used, why it was selected, what each measured and the contribution of each measure to the study objectives.

Table 6.5 Test equipment list

Serial No.	**Variable of Interest**	**Research Objective**	**Gauges**	**Social Research Instruments**			**Accuracy of the Instrument**
				Interview schedule	Question-naire	Structured observation	From Equipment Manuals
1.	A. **Heat** Ambient temperature in the kitchen	1,2,3	Thermo-hygrometer	B 1-4	24	BC 41	±1° C
2.	Outside temperature	1,2,3	Heat index WBGT Meter	A 15		DA 94,95,96,97	±1° C
3.	Wet bulb globe temperature	1,2,3	Heat index WBGT Meter	B 1-4		DA 98	±1° C
4.	Temperature in different areas in kitchen	2,3	Heat index WBGT Meter	B 1-4		DA 97	±1° C
6.	B. **Ventilation and Humidity** Humidity	1,2,3	Air temperature-humidity meter/ hygrometer	B 7-10	34	BD 53-59,62-63, DA 91	±3 %
7.	Relative Humidity	1,2,3	Air velocity meter	B 7-10	36,37	DA 91	±3 %
8.	Air velocity	1,2,3	Anemometer (Air velocity meter)	B 5,6	40	DA 101	±2 %
9.	CO_2 in air	2,3	Air quality monitor	B 5	40	DA 102	±30 ppm +5 % of reading
10.	Oxygen	2,3	Air quality monitor			DA 103	±1 %
11.	C. **Light**	1,3	Light meter (lux)	B 11-16	29	AB 13-15,17-18,25,26, DA 93	±3 %
12.	D. **Acoustics**	1,3	Noise level meter	B 21-25	32,35	BC 39-40,41 DA 92	±1.4 dB
13.	Kitchen area	1,4	Laser measure	27-32	6	AA 8, BD 42,47	

6.6 Data analysis

Quantitative data was collected through a questionnaire survey that evaluated the IEQ in kitchens from a head chef's or kitchen manager's perspective. Subsequently, qualitative data was also collected through in-depth interviews to identify kitchen workers' approaches to IEQ in kitchens. IEQ was measured by the researcher with test equipment. The use of multiple data collection instruments permitted cross-referencing or triangulation of the results towards defensible assessments of IEQ in sampled commercial kitchens.

Roomaney and Coetzee (2018: 3) state that triangulation is an important justification for adopting mixed-methods approach and used when researchers test the validity of the results from combining various methods to study the same phenomenon. Using triangulation allows for the systematic extension of possible knowledge creation by using second methodological proceedings and place findings on more solid ground (Flick 2019: 192). The type of triangulation chosen depends on the purpose of a study and more than one type can be used in the same study. In this study, the focus was on method triangulation. The data collected with three different instruments such as questionnaires, interview schedule and observation checklist with direct observation techniques and direct measurement techniques were combined. Method triangulation is commonly known as multimethod triangulation (Yeasmin and Rahman 2012: 157) which also refers to the combination of qualitative and quantitative data.

The quantitative data collected from the responses to the instruments were analysed using the Statistical Package for Social Sciences (SPSS) Version 25.0. This data can be used for market research, surveys and data mining (Thomes 2018: 1). It is used by various researchers for complex statistical data analysis (Foley 2018: 1).

The data from interviews and questionnaires were thematically analysed. Themes were developed to accord with the variables of interest. Retrieving qualitative data from respondents requires the researcher to do a write up on the information received. Many qualitative statistics are available in the form of narrative (text) writings, that are derived from a variety of sources including interviews, survey questions, papers, published findings, and current documents. Words combine into meanings, but meanings must be sorted, interpretations deliberated and inferences drawn (Flick 2013: 350).

Following Welman *et al.* (2005: 212), these themes were identified before, during and after data collection by means of word counting, pattern recognition, descriptive and interpretative codes. Also, data collection and data analysis were found per David and Sutton (2011: 350) to often fold into each other in the exploratory form of qualitative research. For example, measurement of CO levels in the kitchen and comparison with permissible levels could indicate inadequate ventilation without any further analysis of this data.

Correlation was used to assess reliability, the closer the correlation is to 1.0, the more reliable the scores are. McLeod (2013: 1) posits that if findings from research are replicated consistently, they are reliable. A correlation coefficient can assess the degree of reliability. A reliable test should show a high positive correlation. Multiple logistic regression models used to define the relationship between multiple variables were used to analyse the association between variables.

Multiple regression is used to predict the value of a variable based on the value of two or more other variables. The variable to be predicted is called the dependent variable or criterion variable and the variables used for predicting the value of the dependent variable are called the independent variables.

The next section discusses data preparation and coding, data capturing, and pretesting of instruments which are required to improve the validity and reliability of data collection procedure.

6.6.1 Data preparation and coding

Import.io (2019: 1) appropriately defines data preparation as a pre-processing step where data from one or more sources are cleaned and transformed to improve its quality prior to its use in business analytics. It is often used to merge different data sources with different structures and different levels of data quality into a clean, consistent format. Castle (2018: 1) states that data preparation refers to any activity designed to improve the quality, usability, accessibility, or portability of data. The ultimate goal of data preparation is to empower people and analytical systems with clean and consumable data to be converted into actionable insights.

Flick (2015: 171) claims coding means allocating numerical values to answers. Prior to coding data cleaning is necessary. The first step in data cleaning was removing unwanted observations from a dataset (Ben-Gal 2005: 132). This included duplicated or irrelevant observations. All the three instruments' measurements were cleaned while coding and then input into SPSS. The act of representing data leads to the achievement of analysis. Content analysis was done in terms of units where the work was broken down into its component elements. Structural errors arise during measurement, data transfer, or other types of "poor housekeeping", where the researcher checked for typos or inconsistent capitalisation. Unwanted outliers, especially with humidity measurements were filtered as they could cause problems. Moreover, linear regression models are less robust to outliers (Ben-Gal 2005: 132). According to Elite Data Science (2018: 1), missing data is a deceptively tricky issue due to the fact that the missing value may be informative in itself that particular equipment does not exist in certain kitchens. However, crediting the missing values based on other observations was useful in a few cases.

After data preparation, the qualitative data common themes - words, phrases, meanings within the data were analysed. The questionnaires with close-ended questions and structured observation were pre-coded. The interview schedule was coded after the collection of data as it was unstructured. Here the answers were allocated to categories which were then labelled with numerical values (Flick 2015: 172). Structural coding generally results in the identification of large segments of text on broad topics which form the basis for in-depth analysis within or across topics (Guest and MacQueen 2008: 125). A greater understanding of data was acquired by 'coding up' which raised the validity of the codes chosen.

6.6.2 Data capturing

Data capture refers to any process that converts the information provided by a respondent into electronic format. This conversion is either automated or involves staff keying the collected data (Statistics Canada 2015: 1). The coded data was sent to an approved statistician to be captured for this study.

6.6.3 Pretesting

Initially, an experts' comment on the representativeness and suitability of the questions was obtained. Allowing suggestions to be made on the structure of the questionnaire helped establish content validity and enabled the researcher to make amendments prior to pilot testing. The generation of items during tool development required considerable face and content validity resulting in refined wording and inclusive content. Prior to using tools, questionnaires were pilot tested. The purpose of the pilot test was to refine the instruments so that respondents had no problem answering the questions and there was no problem in recording data (Saunders *et al.* 2009: 394). In addition, it enabled the researcher to obtain some assessment of the questions' validity and the likely reliability of the data collected.

Preliminary analysis using the pilot test data was undertaken to ensure that the data collected enabled investigative questions to be answered. Ten percent of the convenience sample frame was chosen randomly for pre-testing the three tools. The trial run was established to indicate whether the questionnaire would succeed. Pretesting was conducted on fifteen food service workers from three different restaurants to strengthen reliability. The pretesting sample did not form a part of the study sample.

6.6.4 Report on pretesting

Pretesting was conducted on 6 February 2017. The questionnaire was pretested in three commercial kitchens. The manager at a CBD restaurant was impressed with the questions and commented that it would have taken a long time to formulate such questions. He was cooperative and only took 10 minutes to complete the questionnaire. He wanted some clarification on question 5. Question 21 in the questionnaire did not have ‘extractor’ as an option and the manager was confused. Question. 35 on page 7 needed to be clarified to include ranking order and not just ticking. The last question required a yes/no option. One restaurant manager commented that the questions were not up to standard and needed modification. Spelling errors and language corrections were made. This was aided by the managers’ comment that the mistakes in instruments could not be overlooked.

The interview schedule was pretested on 11 February 2017 in three different kitchens. The staff were asked questions near their workstations during their break time. There were no issues encountered in understanding the questions posed, with only a bit of shyness from female kitchen workers.

The gauges were pretested from 15 to 17 February 2017 in three kitchens offering Indian cuisine, Italian cuisine and grill food. On the third day, one of the equipment required an extension cable connection although all the other equipment were battery operated. The CO_2 monitor used batteries quickly due to 24 readings in each kitchen. The equipment was calibrated and hence the readings seemed accurate.

6.6.5 Descriptive statistics

The analyses will present the descriptive statistics in the form of frequencies, percentages, graphs and cross tabulations. Descriptive statistic according to (Sharma 2019: 4) is a representation of the entire population or a sample and provides a summary of the samples and measures done on a study. All descriptive statistics represent the measure of central tendency to help understand the meaning of analysed data. The two main purposes include highlighting the potential relationship between variables, and basic features about variables in a dataset. Descriptive statistics explain a simple summary of various samples, data set, etc. and includes their measures. The findings derived from the qualitative data obtained from the interviews with food service workers are based on themes identified and presented graphically. Quantitative questionnaire data were analysed using descriptive and inferential statistics. Discussion of the latter follows.

6.6.6 Inferential statistics

According to Kothari (2009), quantitative data analysis is helpful because the results are easy to understand as it is quantifiable. Inferential techniques include the use of correlations and chi- square test values and factor analysis which are interpreted using the p-values. Consistent with Field (2013: 52), correlational analyses were conducted to determine the implication of the predictor variables in contributing to the dependent variable.

The exploratory factor analysis (EFA) conducted on the responses formed the sample of 170 workers and maintained a ratio of 5 in the number of observations to the number of variables. Per Comrey and Lee (2013: 1) the each variable that were subjected to factor analysis had at least 5 to 10 observations. Larger sample size can diminish the error in ones' data and so EFA generally works better with larger sample sizes. However, earlier, Guadagnoli and Velicer (1988: 274) proposed that if the dataset has several high factor loading scores (> .80), then a smaller small size (n > 150) should be sufficient. A factor loading for a variable is a measure of how much the variable contributes to the factor (Yong and Pearce 2013: 81). The types of factors are represented graphically, for example, numerical ability is a common factor and communication ability is a specific factor. Moreover, the factor loading scores indicate that the dimensions of the factors are better accounted for by the variables. Next, the correlation ***r*** must be .30 or greater since anything lower would suggest a weak relationship between the variables (Tabachnick *et al.* 2007: 101).

The results of the primary study in chapters seven, eight, nine and ten are presented both as brief discussions and in table form. The study calculated predictions between variables within research instruments as well as across the three different instruments in the food service establishments, namely structured observational schedule, questionnaire for food service managers/head chefs and interview schedule for kitchen workers.

The next step in data mining was sorting through the large data sets to identify patterns and establish relationships to solve problems by data analysis. Factor analysis as the data mining tool, allowed for the prediction of future trends. Factor analysis as a statistical technique was used in this study for data reduction (Costello and Osborne 2005: 2).

6.6.7 Exploratory factor analysis (EFA)

Factor analysis is a correlation method used to combine a number of variables into a limited number of factors that hypothetically represent real-world constructs. According to Widaman (2012: 361), this technique may be considered as the most popular and useful method for identifying underlying dimensions that can mathematically account for behaviour. The basic theory of factor analysis is that for a collection of observed variables there are a set of underlying variables called factors, which are smaller than the observed variables that can explain the interrelationships among those variables (UCLA Statistical Consulting Group 2016:1)

Porritt (2015: x) argues that recent studies have indicated that under the proper circumstances factor analysis may be accurately performed in samples as small as N = 9. A small sample size of 170 food service workers and a sample frame of 33 restaurants provided reliable data. De Winter *et al.* (2009: 168) state that when EFA is well conditioned, it can yield reliable solutions for sample sizes well below 50 with high λ, low f, high p. In some conditions, sample sizes even smaller than 10-beyond the smallest sample size of previous simulation studies were found to be sufficient.

Adonis (2016: 57) adds that the typical use of factor analysis is in survey research, where a researcher wishes to represent a number of questions with a small number of hypothetical factors. Factor analysis was used to establish whether the three instruments in this study, measured the same construct. Several questions in the questionnaire and observation schedule in the present study seem to reflect this trend and were combined to create a new variable. This according to DiStefano *et al.* (2009: 1) was a factor score variable that contains a score for each respondent on the factor. When applied to this study, the factors were interpreted, given names and considered as real things.

The matrix tables are preceded by a summary that reflects the results of the Kaiser-Meyer-Olkin Measure (KMO) and Bartlett's Test of Sphericity (Appendix 3). Field (2013: 816) declares that the KMO measures should be greater than 0.50 and Bartlett's Test of Sphericity less than 0.05. In all instances, the conditions were satisfied, and this allowed for the factor analysis procedure to be applied to the Likert scale items. Certain components were divided into finer components and this is explained in the rotated component matrix.

Association is more specific to dependently linked variables that are highly correlated with another attribute and regression is a commonly used technique (Ray 2015: 2). The author adds that multivariate linear regression is one of the most widely known modelling techniques.

6.6.8 Regression analysis

Given the largely quantitative research design, simultaneous backward multiple regression analysis was appropriate to measure the relationship of the predictive variables to the dependent variable. According to Field (2009: 198), regression analysis enables the prediction of future outcomes based on the predictor variables. Regression analysis is also a powerful statistical method that allows one to examine the relationship between two or more variables of interest (Foley 2018: 1).

The backward method of multiple regression calculates the contributions of each predictive variable by looking at the significance value of the t-test for each predictor (Field 2009: 213). If according to the author, the predictor meets the deletion criterion or not making a statistically significant contribution to how well the model predicts the outcome variable, it is eliminated from the model. The remaining values are examined to evaluate and define their contribution to the outcome of the dependent variable.

Multi-collinearity is a statistical phenomenon in which two or more predictor variables in a multiple regression model are highly correlated (Akinwande *et al*. 2015: 2). The level of multi-collinearity can be measured by considering the predictor variables. The predictor variables should not have a strong relationship with each other. The stronger the relationship between the predictors, the higher the degree of multi-collinearity of the betas (Walker 2011: 7).

Specifically, this study examined the multi-collinearity of the predictive variables per Maher *et al*. (2013: 348) by checking the Pearson Correlation Coefficient between the predictive variables. Moreover, the process involved focusing on the model summary of the backward multiple regression analysis of the data and how it was produced, and the standardised coefficient beta weights of the predictive variables. Before commencing with regression analysis, ANOVA was performed to confirm that the model was correct to permit regression analysis. An alpha of 0.05 was used for all statistical tests.

6.6.9 Types of regression

There are a variety of regression techniques available in SPSS. It can range from simple linear regression, multiple linear regression and more advanced analyses such as logistic regression (Field 2013: 145). Even though there are many types of regression analysis, at their core they all examine the influence of one or more independent variables on a dependent variable (Foley 2018: 1). The different components of regression namely, partial eta square, general linear model: effect size and logistic regression. To determine the magnitude of the effect of one or more variables over the other variables as the elements of different IEQ parameters can influence each other in the commercial kitchen environment.

6.6.9.1 Partial eta-squared

It is an estimate of effect size reported by SPSS, in conjunction with analysis of variance (ANOVA) and generalised linear model (GLM) analyses. Many social scientific journals require reporting estimates of effect size to supplement tests of statistical significance, which is good practice (Field 2013: 561). Effect size-statistical tests such as a t-test tell what degree of certainty to attribute to the possibility that a difference is not an accident but an effect; another important concern is how important the difference is (Draper 2019: 1). Partial eta-squared was calculated as the ratio of the between-groups sum of squares to the sum of the between-groups sum of squares and the error sum of squares. Wherever the p-value was not significant, partial eta squared was used in the present study to establish to what extent a dependent variable was affected by several independent variables.

6.6.9.2 General linear model: effect size

P-values alone do not indicate the size of an effect between variables (Field 2013: 125). In particular, if one variable is a dependent scale (number) variable and the other an independent nominal variable, the interpretation of the relationship is given by the effect size as measured by partial eta squared value (Maher *et al*. 2013: 350). The logical reasons to choose an alpha level other than $p = 0.05$ with which to interpret the statistical significance and the interpretation of practical relationships based on effect size may be more or less conservative, depending on the context (Maher *et al*. 2013: 350). Association between related and dissimilar elements can be established to highlight the implication between elements of IEQ parameters.

6.6.9.3 Logistic regression

Logistic regression is a statistical method for analysing a dataset comprising one or more independent variables that determine an outcome. The outcome is measured with a dichotomous variable - two possible outcomes (Medcalc 2020: 1). Logistic regression is used to obtain the odds ratio in the presence of more than one explanatory variable. The procedure is quite similar to multiple linear regression, with the exception that the response variable is binomial (Sperandei 2014:12). The result is the impact of each variable on the odds ratio of the observed event of interest. The main advantage, according to the author is to avoid confounding effects by analysing the association of all variables together. The researcher used the backward method of simultaneous multiple regression to complete the elements of data analysis.

6.7 Validity and reliability

Reliability means consistency and validity means accuracy which are critical factors in research and is the foundations of good research (Adams and Lawrence 2018: 69). Mohajan (2017: 59) states that validity and reliability increase transparency and decrease opportunities to insert researcher bias in qualitative research and adds that it is judged for rigor and strength based on validity and reliability of a research. Heale and Twycross (2015: 67) claim that rigour refers to the extent to which the researcher worked to enhance the quality of the study which can be achieved through measurement of validity and reliability. The quantitative and qualitative measures have been met to validate the quality of the study with rigour. Qualitative rigour is discussed in section 6.7.4.

6.7.1 Reliability

Reliability refers to the ability, consistency or dependability of an instrument, which is reliable and measures accurately and reflects the time score of the attributes under investigation (David and Sutton 2011: 267). Mohajan (2017: 68) posits that in quantitative research, reliability refers to the consistency, stability and repeatability of results. However, in qualitative research reliability is referred to when a researcher's approach is consistent across research and projects. The appropriateness and reliability of information gathered in an evaluation must be high-quality data that comes from well-defined indicators. Other factors that affect data quality may include instrument design, data collection procedures, training of those involved in data collection, source selection, coding, data management, and routine error checking (Community Tool Box 2019: 12).

Accurate instrument calibration was vital for the current study. Calibration is necessary to ensure that the instruments and devices used to measure parameters are accurate (Amsbary 2012: 2). The most competitive offer from the supply and calibration was chosen. A designated instrumentation engineer from the manufacturing company demonstrated by prior appointment, the procedure to measure all variables of interest.

Trial measurements were taken in an operating kitchen to authenticate each of the instrument readings from test equipment. One of the principal characteristics of an outcome measure in a trial, and any measurement in general, is its reliability (Lachin 2004: 553). Measurement reliability concerns the consistency of measurement also known as internal consistency reliability (David and Sutton 2011: 267).

According to Yin (2013: 115), one of the best ways to enhance reliability is observation; however, it requires multiple observations at different times. Ambient temperatures and airflow in the kitchen were measured at different intervals. The reliability of the instrument can be judged by estimating how well the items that reflect the same construct yield similar results; the consistency can be checked. For example, higher values of ambient temperature, wet bulb globe temperature and humidity mean higher thermal stress for workers. Reliability is a prerequisite for validity, but reliability alone is not sufficient to demonstrate validity. Hayashi *et al.* (2019: 98) state that validity and reliability of research and its results are important elements to provide evidence of the quality of research in the organisational field.

6.7.2 Validity

There is greater evidence of validity in quantitative studies than in qualitative research studies (Hayashi *et al*. 2019: 98). Flick (2019: 543) comments that in qualitative research, validity typically receives more attention than reliability. As there is diversity within qualitative research methods and techniques, there are no universally accepted criteria to assess validity in qualitative studies (Hayashi *et al*. 2019: 98).

Face to face interviews, test equipment measures, and self-administered questionnaires are valid instruments of collecting data. The interviewees were briefed on the subject matter prior to interviews, thereby facilitating validity and reliability by enabling them to gain an understanding of the information being requested (Saunders *et al.* 2009). Once the researcher generated the initial pool of items, the next step involved rigorous discussions (Kumar 2011: 39) between researcher and field experts to review the items in terms of content adequacy. Content validity is the extent to which a research instrument accurately measures all aspects of a construct (Mohajan 2017: 73). To assure content validity, items for each construct were generated from a review of associated literature.

Cronbach's α is the most commonly used test to determine the internal consistency of an instrument (Heale and Twycross 2015: 67). Internal consistency of the questionnaire and structured observation were estimated by Cronbach's alpha. An alpha of 0.70 or higher was desired and values upto 0.899 were derived as given in Appendices 25 and 26 on correlations. The validity of a study refers to how accurately the instruments measured what it is supposed to measure (Adams and Lawrence 2018: 71). Amongst others, this was achieved by calibration of test equipment. According to Veal (2011: 344), the multiple methodologies and data sources used by the typical case study method offer the possibility of achieving a high level of internal validity. Multiple method in the study consisted of instruments namely, observation checklist, questionnaire and interview schedule. Data was sourced from a range of food service workers. Furthermore, in-depth interviewing and long-term observation allow for greater internal validity (David and Sutton 2011: 20).

Pilot testing or pretesting adds to validity of the instrument. Trochim *et al.* (2016: 28) states that internal validity refers to the degree to which conclusions are made about causal relationships. However, the author adds that one important feature of internal validity is that it is only relevant to the specific study in question; it has zero-generalisability. Good experimental techniques, in which the effect of an independent variable on a dependent variable is established can prove internal validity (Abowitz and Toole 2010: 112). Airflow is an independent variable that affects humidity which in turn affects thermal stress. It seems the higher the airflow, the lower the humidity and thermal stress.

Table 6.6 summarises the measures followed to enhance quality of the study by means of the various quantitative and qualitative measures to ensure validity and reliability.

Table 6.6 Enhancing quality of study (adapted from Mesh Guides 2021: 1)

Qualitative data	Demonstrated in	Quantitative data	Demonstrated in
Researcher bias / objectivity / honesty	Section 6.7	Appropriate statistical analysis of the data	Section 6.6
Design of research tools	Section 1.7.1 and 6.3.3	Design of research tools	Section 1.7.1 and 6.3.3
Sample selection	Appropriate sample selection Interview schedule of 170 food service workers	Sample selection	Appropriate sample selection Observation checklist of 33 food service establishments 33 Questionnaires of head chefs/kitchen managers
The use of triangulation	Section 6.7.3	Sample size	Section 6.5.1
Rigour	Section 6.7.4	Rigour	Section 6.7.4

Trochim *et al.* (2016: 129) categorises validity according to the quality of measurement. The author points out that face validity means good translation of the construct. Construct validity is the extent to which a research instrument or tool measures the intended construct. Construct validity was improved in the study by assuring face validity from consulting industry experts to assess that the instruments measure what it claims to measure. According to Bryman (2016), face validity reflects the content of the concept. The interview schedule and questionnaire were shown to the experts in the field for approval. Participants' consent was obtained prior to the interview.

After the interview, a summary of the responses was reviewed with the respondent to ensure content validity. The more the scale items represent the domain of the concept being measured, the greater the content validity (Sekaran and Bougie 2016: 227). The authors add that convergent validity is a type of construct validity that is estimated using correlation coefficients. The thermal stress faced by food service workers and observed by head chefs and kitchen managers elicited by the questionnaires was correlated by observation checklist and gauges in the current study to satisfy convergent validity tabled in Appendix 26.

6.7.3 Triangulation

Beyond the validity measures in the prior section, the application of triangulation raised the internal validity, especially of the qualitative data. Flick (2019: 191) claims that triangulation refers to the combination of different methods, study groups, local and temporal settings, and different theoretical perspectives in dealing with a phenomenon. Prior study by Miles *et al*. (1994) discloses that triangulation in social science research refers to a practice by which a researcher wants to confirm an outcome by showing that independent measures of it agree with or, at least, do not contradict it. The type of triangulation chosen depends on the purpose of a study and more than one type of triangulation can be used in the same study.

In this study, the focus was on methodological triangulation by developing a strategy for combining the data collected from all the three instruments namely, questionnaires, interview schedule and direct observation and physical measurement techniques. Triangulation by this method is commonly known as multimethod triangulation which can be within a method or between methods (Yeasmin and Rahman 2012: 157).

Method triangulation was applied with the quantitative data from the observation schedule and qualitative data obtained from the interview schedules, as well as the questionnaires and compared. All the IEQ parameters in the commercial kitchen environments were recorded with testing equipment and noted for physical observation to compare with the opinions of food service workers and head chefs.

6.7.4 Qualitative rigour

Cypress (2017: 254) claims that rigor is defined as the strength of a research design and the trend is to use the term rigor instead of trustworthiness. The author further adds that to ensure reliability and validity in qualitative research, strategies for ensuring rigor must be built into the research process.

Attending to rigor throughout the research process will have important ramifications for qualitative inquiry.

Riege (2003: 84) argues that validity and reliability of case study research is a key issue. The author introduces the notion of different ways of judging the quality of case study research including credibility, trustworthiness or transferability and replicability or confirmability and dependability. According to Denscombe (2014: 297), credibility is the extent to which qualitative researchers can demonstrate that their data are accurate and appropriate through the use of a technique like respondent validation asking respondents to comment on and confirm the findings. Credibility criterion involves establishing that the results of qualitative research are believable from the perspective of the respondents in the research; the respondents are the only ones who can rightfully judge the credibility of the outcome (Trochim *et al.* 2016: 72). Flick (2019: 548) argues that credible results will be produced by an extended arrangement and persistent observation in the field and the triangulation of different methods, researchers and data.

Dependability involves the researcher demonstrating that their research reflects processes and results that other researchers can see and weigh in terms of how far they establish reputable techniques and rational decisions (Denscombe 2014: 298). Dependability emphasises the researcher's obligation to describe the ever-changing research context. Flick (2019: 548) emphasises that dependability is checked through a process of auditing data.

According to Denscombe (2014: 299), transferability is the information needed to infer relevance and applicability of the findings to other people, settings, case studies and organisations. (Trochim *et al.* 2016: 72), however, mentions that transferability refers to the degree to which the results of qualitative research can be generalised or transferred to other contexts or settings. This is similar to external validity. Transferability is primarily the responsibility of the researcher doing the generalising. The judgement of how sensible the transfer is of the results to another context is achieved in the case study context through the choice of cases included in the research.

Confirmability involves recognising the role of the self in qualitative research and keeping an open mind by not neglecting the data that do not fit the preferred analysis and checking rival explanations Denscombe (2014: 299). Trochim *et al.* (2016: 72) states that qualitative research tends to accept that each researcher brings a distinct perspective to the study. Confirmability refers to the degree to which the results could be confirmed by others. The researcher can conduct a data audit that examines the data collection and analysis procedures and make judgements about the potential for bias or distortion.

Additionally, triangulation of data as adopted in the present study can be a useful tool to demonstrate confirmability.

6.8 Anonymity and confidentiality

Trochim *et al.* (2016: 42) and David (2019: 1) assert that anonymity means that there is no way for anyone including the researcher to personally identify participants in the study. The latter author adds that it also means that any study conducted face-to-face or telephonically cannot be considered anonymous, which rules out virtually all qualitative research that involves interviews.

Confidentiality, on the other hand, means that the participants can be identified, but their identities are not revealed to anyone outside of the study; only the researcher knows the identities of the participants, and measures are put in place to ensure that participants' identities are not revealed to anyone else. Confidentiality is ensured through proper data management and security. Trochim *et al.* (2016: 42) claims that confidentiality means that the researcher makes a promise that identifying information will be known only to the researcher unless circumstances dictate exceptions to maintain the well-being of the participants.

Flick (2019: 143) argues that anonymisation in data collection is a challenge to deal with. This is prevalent during data management when participants' personal-identifying information can be linked to their data using identity numbers or pseudonyms. Hence, personal-identifying information needs to be stored separately from the data. However, Surmiak (2018: 1) claims that revealing the identity of specific vulnerable study participants based on their request may empower them in certain circumstances because their voices can finally be heard.

Case studies are about human affairs and hence it is important to protect human subjects. The researcher should take special care and be sensitive to the participants by maintaining their privacy and confidentiality (Yin 2011: 78). Responses and results from research are to be kept confidential always to respect participants' dignity and right to privacy. The purpose of the research was explained to all respondents in the form of a covering letter. The participation was voluntary, and the researcher was available on-site to answer any question.

Whether the study is anonymous or confidential, it is important to inform participants about what information the researcher will collect from them and how their identities will be protected. An informed consent form is the best way to explain the nature of the data collection and to assure participants that their privacy will be protected. The restaurant kitchens, managers and head chefs, as well as the identity of kitchen workers, were coded during the data entry process to maintain anonymity and confidentiality. In terms of data security, researchers should follow all security measures their Institutional Review Board requires, such as keeping paper and pencil data in locked file cabinets, password-protecting electronic data, and securely destroying the data after the research is completed.

In this field study, the participating organisation consented to the research based on confidentiality and so afforded an opportunity to understand the environmental ergonomics of commercial kitchens.

6.9 Ethical considerations

Conducting ethical research is more than simply doing the right thing (Mandal *et al*. 2011: 1). Ethical principles are moral values and ideals. The researcher built a position of trust and treated respondents with respect and indicated that the interviewer is interested in them as individuals and accepted their uniqueness. The potential participants were informed of the topic, procedures, risks and benefits of participation prior to consenting to the study. The significance of the study and their role in contributing to the betterment of their work environment by concerned parties was explained to all food service workers. Protecting research participants from unethical treatment and violation of rights is a mandated responsibility of all investigators conducting research with human subjects (Kue *et al.* 2018: 114). As the study traverses cultures, the researcher acknowledges the sensitivity of matters relating to cultural specific behaviour. Ethical clearance was obtained from the University Research and Ethics Committee who issued ethical clearance level 1 for this study in 2015.

6.10 Conclusion

This chapter charted the methodological and essential to the study was based. It began with a methodology discussion and the justification for methodological choices. Details of the questionnaire, semi-structured interview techniques and observation by physical measures, and how they were triangulated to substantiate findings and to ensure the validity and reliability of the first-hand verdicts that were presented. The next chapter discusses the investigation of the exploration study with questionnaire, interviews and observation checklist. Chapter Seven is an analytical chapter which will focus on the critical evidence acquired. In addition, data from the questionnaires, interview schedules and test instruments will be analysed and discussed.

CHAPTER SEVEN

DATA PRESENTATION, ANALYSIS AND DISCUSSION: HEAT AND THERMAL COMFORT

7.1 Introduction

The previous chapter examined the methodological choices for this investigation. This chapter will deliberate on data collected on heat and thermal comfort variables. Firstly, thermal stress based on individual factors of food production workers will be discussed, followed by kitchen activities, type of equipment and design elements. Study variables will be examined by way of correlation, factor analysis and regression models. The findings will be presented according to the emerging themes.

7.2 Adaptation to heat in kitchen

Human thermoregulation and acclimatisation are fundamental constituents of the human coping mechanism for environmental heat exposure (Kondo *et al.* 2009: 35; Hanna and Tait 2015: 8034; Nikolopoulou and Lykoudis 2006: 12). According to the latter, variations in thermal tolerance can be intensified by ethnicity and cultural differences, for example, individual genotypes that include skin colour and type of nose. Ethnic differences in thermoregulatory responses in exposure to heat by Qiu *et al*. (2020: 984) indicate that Chinese men preferred higher comfort temperature than British men. Moreover, it includes individual factors that determine physiological adaptation comprising of age, gender, fitness, body fat and physical activity. Table 7.1 indicates a selection of relevant personal variables from the present study.

Table 7.1 Mean values of personal data from the current study

Physical criteria	N	Minimum	Maximum	Mean	Std. Deviation
Age (years)	170	19	62	31.28	8.55
Height (m)	170	1.45	1.83	1.59	0.93
Weight (kg)	170	42.00	157.00	73.1567	15.46
BMI (kg/m^2)	170	18.70	47.90	28.5766	5.60

7.2.1 Age

Stillman (2019: 86) reports that the severity of extreme heat impacts the aged population, among others, negatively. Heat stress is expected to further increase due to an aging population; Schuster *et al.* (2017: 1) report that age has an association with heat impairment. Age is important in the consideration of individual subjective thermal strain of food production staff as indicated by Hanna and Tait (2015: 8046), for its role in thermoregulation, and Ravindra (2015: 56), for its maximum influence on thermal comfort. Table 7.1 shows that the average age of respondents is 31.28 years with a standard deviation of 8.56 years.

Fraser (2017: 1) moreover, asserts that the risks related to the workforce are increasing. The impact of temperature on health and mortality risk among the older population between 65 and 75 years is the highest (Deschenes 2014: 614). Soebarto *et al.* (2020: 155) accord with the author that elderly are vulnerable to heat. Younger people acclimatised better than their older counterparts; thermoregulatory abilities may be compromised due to age or disease among elderly (Hansen *et al*. 2011: 4724).

The present study indicates that 3.5 % fall in the category of older population. Prior studies involving heat stress in kitchens by Singh *et al*. (2016: 7), and Subramaniam and Murugesan (2015: 525) found a similar distribution of age among kitchen workers. On the other hand, Haruyama *et al.* (2010: 141) report that almost 16 % of kitchen workers in a Japanese study were over 55 years of age, placing them at higher risk of heat stress. Section 7.3.2 indicates a high factor loading of 0.801 for age with other individual factors demonstrating that age plays a major role in coping with heat**.** Van Hoof *et al*. (2017: 123) argue that the current models for assessing thermal comfort are not sufficiently accurate for older adults.

7.2.2 Race and comfortable lifestyle

An important factor in the context of human heat adaptation relates to individual genotypes that are anticipated in Objective 3. In this regard, the role of ethnicity appears debatable. Schneider (2016: 536) claims that within each race, there is considerable variation among individuals in their sensitivity to heat and in their ability to acclimate. In a pioneering study, Wyndham *et al.* (1964: 598) assert that although superior in the unacclimatised state, the Bantu (African) does not appear to have an inherent advantage in the ability to regulate the body temperature as compared to Caucasians. Heggie (2019: 18) argues that race and place remained intertwined in assumptions about the way human bodies respond, to their environments.

In the current study, majority of food production workers were Africans (90 %), followed by Indians (7.6 %). However, the ratio between the Africans and Caucasians is much higher for head chefs and kitchen managers, even though Africans still dominate employment in commercial kitchens in the sample investigated. This trend is in line with the demographic figure of SA (Statistics SA 2017: 1). There are no reported studies in the literature on the effect of race and heat adaptation among kitchen workers. However, Lambert *et al.* (2008: 104) presents physiological and morphological differences between groups living in different environmental conditions where variation in birth weight, body shape, composition and skin colour, and the phenotype are very clear. The ratio of different ethnicities among head chefs and kitchen workers is also comparable to the demographic profile of South Africa. The comfort of workers at the household level where they rest helps the reduction of health impacts of heat (Frimpong 2015: 5). Zander *et al.* (2015: 650) claim that hot sleepless nights may reduce productivity the following day.

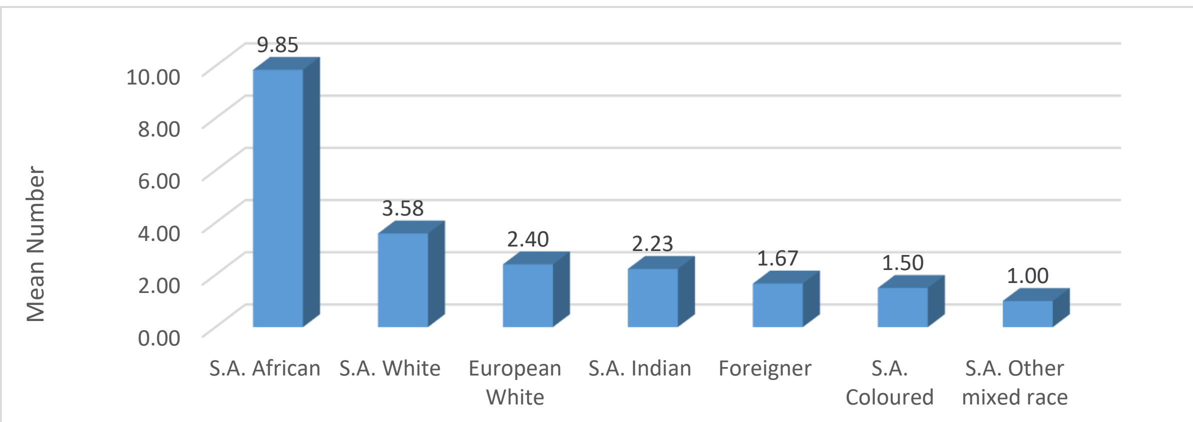


Figure 7.1 Average number of head chefs and kitchen managers by race

The comfortable lifestyle of workers was measured with their ability to use an air-conditioner at their residence and driving a car to work. These two factors were adopted as indicators to ascertain whether it helps workers to be well-rested at home after work and whether such individuals are at lower risk of heat stress if they cool their bodies adequately at night time (Frimpong 2015: iii). Further discussion on variable comfortable lifestyle is discussed in sections 7.5.3 and 7.7.1.

The cross-tabulation between the kitchen worker's ethnicity/cultural background and maintaining a comfortable lifestyle was found to be statistically significant. People of different ethnic backgrounds possess different attitudes, values, and norms that reflect their cultural heritage (Idang 2015: 98). Empirical investigations of the effects of cultural heterogeneity in kitchens are virtually non-existent.

The cross-tabulation between the kitchen worker's ethnicity/cultural background and driving a car to work was found to be statistically significant. Additionally, the cross-tabulation between the kitchen workers with physical fitness and maintaining a comfortable lifestyle was found to be statistically significant (Appendix 26).

Section 7.3.2 determines a high factor loading of 0.850 for race, along with other individual factors. The magnitude of the loading infers that race or ethnicity is a key factor in coping with the heat. The logistic regression in Section 7.6.7 on heat (°C) near the stoves as experienced by kitchen workers is affected by race.

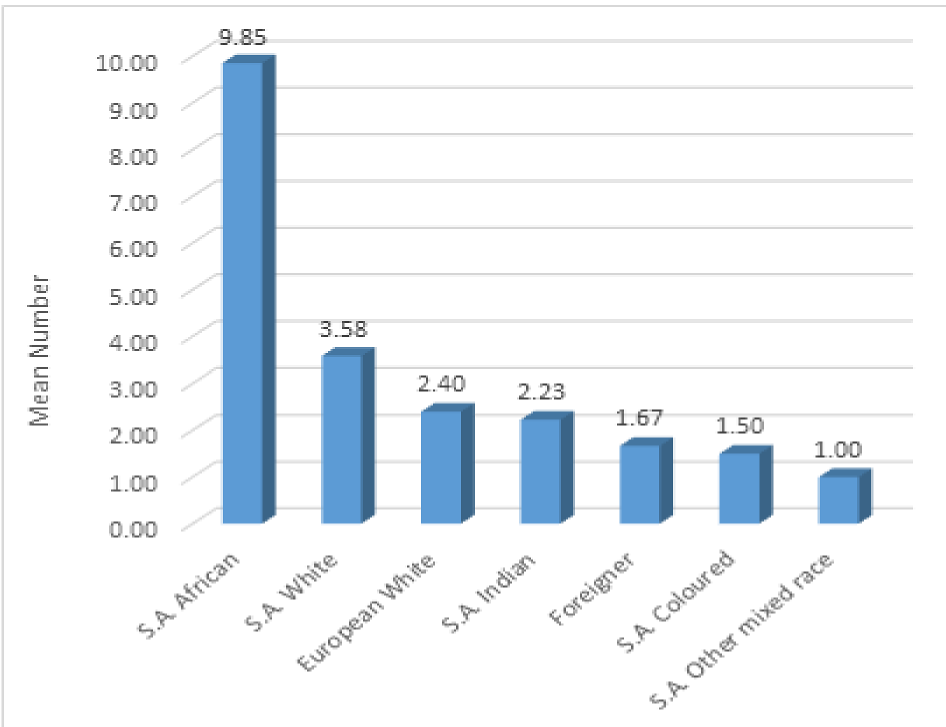


Figure 7.2 Ethnicity amongst sampled kitchen workers in Durban

There were significantly more African employees than the other race groups (89.5 %) ($p < 0.001$). A notable variation is observable in the nationwide SA race profiles, as per Index Mundi (2020), described as Black Africans: 80.9 %; Coloured (Mixed-race): 8.8 % Whites: 7.8 % ; and Indian: 2.5%

7.2.3 Gender

Ravindra (2015: 56) asserts that gender has the maximum impact on thermal comfort along with the inference of Farnell *et al*. (2008: 238) that gender may influence an individual's ability to thermos-regulate. Lisman *et al*. (2014: 1335) report that the association between gender and heat tolerance test

(HTT) performance is controlled by anthropometric and fitness measurements. Alarmingly, 42 % of females were classified as heat intolerant in comparison to only 27 % of males in the military. Alshaikh and Alhefnawi (2020: 391) find that males are more sensitive to hot temperatures than females.

The ratio of males to females was approximately 1:2 (36.3 %: 63.7 %) respectively ($p < 0.001$) in the current study (Table 7.2). This statistic accords with Logeswari and Mrunalini (2017: 608) who report that the majority of the workers in the hostel kitchens were female (75 %) and only 25 % were male. However, Singh *et al.* (2016: 7) report a male-only study of kitchen workers in North India.

Gender differences in heat loss thermo-effectors are explained by morphological variations in the ratio between body surface area and mass between males and females (Notley *et al*. 2017: 545). Lundgren *et al.* (2013: 8) contends that women show better tolerance to humid heat than men, whereas men have enhanced tolerance for extremely hot and dry environments likely to be attributed to the lower sweat rate of women (Xiang *et al*. 2014a: 98). This means that female kitchen workers cope better than men in the kitchen due to moist heat. Rupp *et al*. (2015: 184) conclude that women are less sensitive to humidity than men.

Table 7.2 Percentage of men and women in the kitchens

Gender	Frequency	Percent
Male	61	35.9
Female	109	64.1
Total	170	100.0

The role of gender was further amplified in cross-tabulation between the kitchen worker's gender and BMI that was found to be statistically significant. The weight of South African kitchen workers was notably higher in the range from 42 to 157 kg with standard deviation of 15.46 kg. Sixty-four percent (64 %) of kitchen workers were female, and 50 % of them were overweight. Thirty-six percent (36 %) were males and 71 % had normal weight. The BMI among the sampled kitchen workers varied from 18.70 (underweight) to 47.90 (severely obese) with a mean of 28.57, which indicates normal weight. In contrast, Haukka *et al.* (2012: 488) report that 15 % of Finnish female kitchen workers were obese and 33 % were overweight**.**

Section 7.3.2 allocates a factor loading of 0.780 for males who cope with the heat better than females with other individual factors demonstrating that gender plays a vital role in coping with the heat. It is implied from Lundgren *et al*. (2013: 8) that men cope better with radiant heat generated from grillers and ovens. The variation in average BMR and body heat production between men and women explains that there is a comfort temperature difference between males and females (BBC News Magazine 2015). According to Devlin (2017: 2), women have a lower BMR than men and the skin temperature for women tends to be lower. In general, females are more sensitive to cold conditions (van Hoof *et al*. 2017: 124).

The logistic regression in Section 7.3.3 reveals that gender with a β coefficient of 3.257 and VIF = 1.209 are factors affecting BMI of a kitchen worker. The association between variables across instruments informs that gender is closely associated with other individual factors, years of employment and type of kitchen.

7.2.4 Height, weight and body mass index

Another main element in the context of human heat adaptation relates to worker body mass index (BMI) that is elicited in Objective 3. In this regard, the role of height appears uncertain.

BMI (Quetelet Index) is determined by height and weight. Section 7.3.3 indicates that in the present study, a close association exists between gender, height and BMI, which is statistically significant. As p= 0.046 and less than the significance level of 0.05, is strong evidence to conclude that the variables are associated. According to Hillis (2018:1), BMI reflects health and fitness level, with height being an essential component of BMI. The taller a person is, the greater his fitness and BMI, weight being constant. A short person should maintain a lower weight to improve his BMI. Large differences in height are perceived with lower heights among Indian cooks measured by Singh *et al.* (2016: 7) when compared to South African kitchen workers where more than 90 % workers were ethnically African. The height of kitchen workers in Table 7.1 varied from 1.45 m to 1.83 m with an average of 1.59 m.

Parameswarappa and Narayana (2014: 865) and Habibi *et al*. (2016: 1) in respect of weight, observe a higher risk of heat strain in overweight subjects. The weight of kitchen workers in the current study in Table 7.1 varied in the range 42 to 157 kg with a SD of 15.46 kg. On the other hand, Singh *et al.* (2016: 7) found that workers in India have a range of 44 to 86 kg and Sajedefar *et al*. (2017: 3) report a mean weight of 79±6.5 kg in hospital food services in Iran. Workers at greater risk of heat stress included those who are overweight (NIOSH 2015: 37).

Section 7.3.2 interestingly divulges that weight has a moderate factor loading of 0.672 into the S=socio-economic Index along with other individual factors. Given the lower-income country status of South Africa, people with higher socio-economic status (SES) were more likely to be obese. Joh *et* *al*. (2013: 17) report that men had a higher prevalence of weight under estimation that is lighter than their measured BMI status (24.5 vs 11.9 %) than women. While kitchen workers with higher socio-economic status are more likely to be obese (Najafi *et. al* 2020: 1), shift times of kitchen work render kitchen workers susceptible to raised BMI.

Obese peoples' ability to dissipate heat is reduced despite a higher body surface area (Parameswarappa and Narayana 2014: 865) which is an important factor in the context of human heat adaptation relating to individual body fat which contributes to Objective 2 and Objective 3. Rupp *et al*. (2020: 813) find that overweight occupants are more likely to express warm discomfort than non-overweight occupants. Lipczynska *et al*. (2020: 411) find that the overweight and obese participants preferred lower temperatures compared to normal-weight and underweight participants.

Obesity among a majority of food preparation and serving workers (52.2 %) is reported by Gu *et al.* (2014: 5) in a US study. Adopting WHO definition of obesity when BMI is > 30, Rabeiy (2018: 4) reports that only 16 % of the bakery workers in Egypt were obese. Eighty-two percent (82 %) of the women and 36 % of men aged 35 to 70 years in Langa, SA are overweight or obese. Okop *et al*. (2016: 3) claim that South Africa has a high burden of obesity in this age category. Cois and Day (2015: 1) state that the overall mean BMI was 26.8 kg/m², with 42.1 % of South Africans within the normal BMI range. Females had a significantly higher mean BMI (29.0 kg/m²) than males (23.9 kg/m²).

Guided by the definition of obesity where BMI ≥ 30 (Hillis 2018: 1), the present study found that a minority of 29.8 % of kitchen workers in Figure 7.3 had normal BMI, with the remaining workers being overweight to obese. It seems BMI in the range of 20-25 is considered normal range that is important to endure physically strenuous kitchen work, which affects acclimatisation. The risk of heat illness increases with excess body fat (Bedno *et al.* 2014: 466).

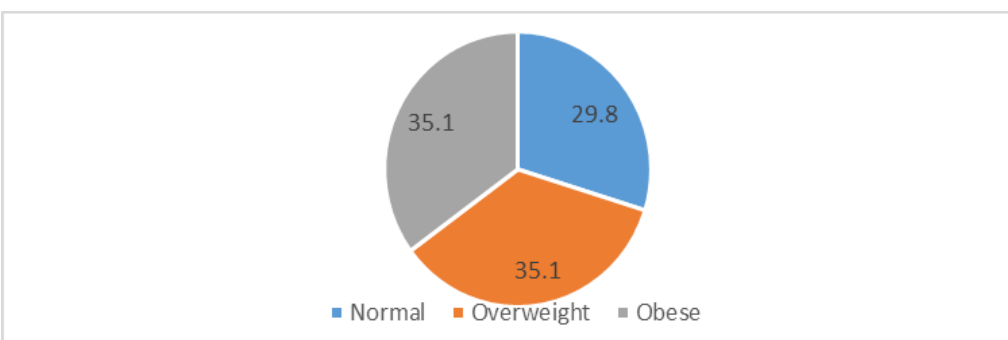


Figure 7.3 BMI of kitchen workers in percentage

7.2.5 Fitness and physical activity

An important factor in the context of human heat adaptation relates to individual fitness foreseen in Objective 2 and Objective 3. In this respect, the role of fitness and physical activity are closely related. According to Parameswarappa and Narayana (2014: 865), physical fitness is a significant feature for assessing heat strain.

Schuster *et al.* (2017: 1) moreover, prove that age as the most common risk factor is out- performed by fitness as a dominant risk factor. The potential of health and fitness to reduce urban heat stress risk could be an effective heat adaptation strategy, whilst Lisman *et al.* (2014: 1339) report that higher cardio-respiratory fitness is associated with heat tolerance, Tuomaala *et al.* (2013: 2309) found that individual fitness seems to cause significant increase in thermal sensation index values. Smit *et al.* (2011: 450) add that physical inactivity and unfitness can lead to health problems. Importantly, Fan *et al*. (2015: 1) have reported an inverse association between BMI and physical activity in China.

In this regard, almost 86 % of the kitchen workers believed that they possessed fitness although Table 7.3 intimates a smaller percentage. Nearly 30 % of head chefs/managers felt that fitness did not affect coping with heat in the kitchen; 70 % felt that it played an important role, in the earlier mentioned view shared by Lisman *et al*. (2014: 1339) and Tuomaala *et al.* (2013: 2309). Almost 42 % of the workers engaged in some physical activity; walking being the most prevalent activity (46 %) on different occasions. Football seems to be the most popular sport among the staff. Only cycling seems to be significant besides walking. More than a third of the respondents walked every day (35.1 %) ($p < 0.001$). Very few cycled regularly ($p = 0.007$). There was no major difference in terms of frequency regarding the other activities ($p > 0.05$). Figure 7.4 indicates fitness assumption among kitchen workers ($p < 0.001$).

Table 7.3 Frequency of Physical activity of kitchen workers

	Percent					chi-square
Physical Activity	**Everyday**	**3-4 Times**	**Twice a week**	**Once a week**	**Never**	**p-value**
Walking	35.1	7.6	2.3	0.6	0.6	**0.000**
Jogging	1.8	5.3	2.3	4.7	1.8	0.188
Running	0.6	4.7	2.9	3.5	4.1	0.248
Cycling	0.0	0.6	0.0	0.0	5.8	**0.007**
Swimming	1.2	1.8	0.0	1.8	6.4	0.261
Physical exercise-gym	0.0	4.7	2.3	1.8	4.1	0.378
Any other	3.5	3.5	2.3	4.1	0.6	0.314

Thermal comfort theory suggests that psychological and behavioural factors significantly influence how people evaluate thermal environments (Table 7.4 page 156). Among the factors associated with psychological adaptation, experience, expectations and perceived control are most influential (Lin 2009: 2020). For example, experience can play a role in coping with heat; the author theorises that thermal sensitivity is lower in the hot season than in the cool season. However, Dillender (2019: 34) indicates that workers in climates where hot days are rare are better able to deal with a hot day than workers in climates where hot days are common.

Cois and Day (2015: 1) reported that a strong positive trend in BMI remains in South Africa and obesity prevalence is likely to increase with physical inactivity. D'Souza *et al*. (2015: 8) mentions that female obesity is highly dependent on race and ethnicity.

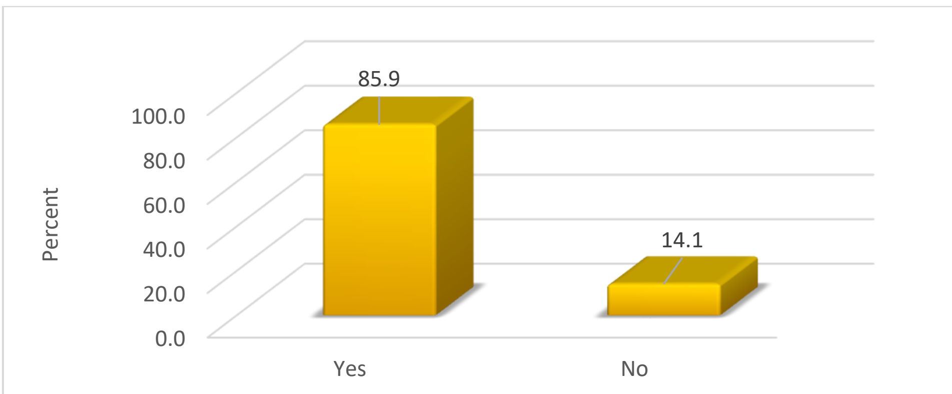


Figure 7.4 Assumptions among kitchen workers of personal fitness

The cross-tabulation between the kitchen worker's possessing physical fitness and BMI was found to be statistically significant. The association between physical activity (PA) and BMI was weak in non-obese individuals. Consequently, these individuals have lower heat adaptation. In contrast, BMI was significantly associated with PA in obese individuals (Hemmingsson and Ekelund 2007: 663); indicating lower heat stress. The inverse relationship between physical activity and body fat is well known.

All Asian populations studied had a higher body fat (BF) at a lower BMI compared to Caucasians. The high BF % at low BMI can be partially explained by variances in body build, trunk-to-leg-length ratio, slimness and muscularity. Hence, the association between BF % and BMI is ethnic-specific. For comparisons of obesity dominance among ethnic groups, universal BMI cut-off points are not suitable (Deurenberg *et al.* 2002: 141). However, measuring worker body fat was beyond the scope of this study. Section 7.3.2 reveals that fitness has a moderate factor loading of 0.554 into demographics along with other individual factors, which means that fitness is a player factor in coping with the heat.

7.2.6 Years of employment and work experience

Daily routine activities involving physical activity in the ambient heat lead to partial seasonal acclimatisation that improves population heat tolerance (Hansen *et al*. 2011: 4724). Acclimatisation may therefore, be the primary component of the human coping mechanism for environmental heat exposure. With this in mind, Lundgren-Kownacki *et al.* (2019: 10) suggest adopting a systematic heat exposure regime to induce acclimatisation; a view shared by Singh *et al*. (2016: 11) in respect of kitchen employees being given time to adapt to the workplace prior to taking up the job. The researcher proposes that time in the kitchen context that helps to acclimatise workers in coping with heat must necessarily refer to the years of employment in kitchens and the accompanying work experience as important variables to assist in responding to Objective 3 of this study.

In this regard, 47 % (f=16) of head chefs strongly agreed that work experience played a substantial role in coping with heat; also, the years of employment contributes to work experience and acclimation to heat. Kitchen workers revealed that the work experience varied from three months for a trainee chef to 35 years for a 60-year-old chef (Table 7.5). Acclimation among experienced chefs and kitchen workers helps to cope better with heat stress in kitchens compared to newer staff; however, workers above 50 years might find it difficult to cope (Kalkowsky and Kampmann 2006: 466). Elderly, or those aged 60 years or over are vulnerable to heat (Soebarto *et al.* 2020: 155). The relationship with years of employment indicates that the greater the number of years worked, the lower the heat experienced near stoves due to thermal adaptation until aging sets in from 50 years onwards. Masuda *et al*. (2019: 38) claims that thermal adaptation of workers may be underappreciated. Earlier mentioned studies on kitchen heat in section 7.6.2 do not discuss acclimatisation; however, studies related to mines, forestry and agriculture do review acclimatisation factors (Appendix 1).

Table 7.4 Years of acclimatisation

Acclimatisation	N	Minimum	Maximum	Mean	Std. Deviation
Years of employment	170	.03	35.00	4.3997	4.77884
Working hours	160	5.0	13.0	8.834	1.9808
Years spent in kitchen cooking	165	.08	37.00	6.5778	6.55224

7.2.7 Job position

The task environment of kitchens varies considerably. For example, chefs in the Hot Kitchen, beforehand cook food items for the Cold Kitchen or Garde Manger. Hence, heat exposure depends on the job position of the chef. Similarly, executive chefs do not spend much time near stoves. Most executive chefs primarily handle administrative tasks and may spend less time in the kitchen (Truity 2017: 1). Likewise, cleaning kitchen workers perform the final step in the food production cycle are away from hot stoves.

Table 7.5 Roles of kitchen staff

	Job position	Frequency	Percent
Supervisors	Owner	6	18.18
	Head chef or Kitchen Manager	27	88.82
	Total	**33**	**100.0**
Workers	Food preparation	30	17.64
	Sous chef	21	12.4
	Pizza chef/tandoor	19	11.2
	Griller	16	9.4
	Commis chef	12	7.1
	Scullery worker	12	7.1
	Fryer	11	6.5
	Cleaning assistants	11	6.5
	Expeditor/runner	11	6.5
	Pasta chef	10	5.9
	Pastry chef	7	4.12
	Salad chef	3	1.8
	Kitchen assistant	3	1.8
	Pizza roller	3	1.8
	Trainee	1	0.6
	Total	170	100.0

The collective data indicates that the higher the position, the lower the heat experienced near stoves. There is strong evidence to conclude that the variables are negatively associated. With p=0.039; less than the significance level of 0.05, this p-value indicates that the observed difference in more than 3.9 % of sample would be due to random sampling error.

It is evident from Table 7.5 that food preparation is an essential task before cooking. Almost 18 % of kitchen workers from 33 restaurant kitchens were tasked with food preparation and supply to chef for further cooking process. Almost 49 % of staff were directly involved in cooking activities, whereas 34.3 % were involved in other related activities. Kitchens offering Italian cuisine had chefs (18.8 %) preparing pizza dough, pizzas and pasta. These ratios vary from the report of Haruyama *et al.* (2010: 140) in Japan; 45 % of the kitchen staff were involved in cooking, and only 8.4 % were involved in washing. Nearly 47 % of the workers were involved in other activities. It seems that these variations could be due to the varied cuisines noted in the current study. Section 7.6.3 reveals with logistic regression that heat (°C) experienced by chefs near stoves is affected by their job position along with other variables.

Dishwashing and cleaning assistants, on the other hand, are exposed to humid heat as hot water generates humidity and confirmed by Matsuzuki *et al.* (2013: 174) of similar results where the kitchen working temperature is high. Extreme heat generating equipment are among the perils that cooks navigate in their daily work environment (Laiskonis 2016: 1) as in the case of a prep cook or line cook. For the same reason, a cook's occupation is considered to be the third worst job in America (Galarza: 2015: 1).

7.2.8 Worker shift

Richter *et al*. (2016: 2) argue that the desynchronisation of the biological clock triggered by extreme exhaustion and sleeplessness are common among shift workers and can lead to undesirable effects such as poor work performance, accidents at work, nonattendance, reduced quality of life and signs of depression. Night work, in particular, seems to cause a circadian rhythm sleep disorder called shift work disorder (Saksvik-Lehouillier 2015: 1). Moreover, work in rotating shifts can contribute to poor health, especially in elderly and women. Bonnell *et al.* (2017: 1) identified a number of dietary-specific shift-related issues that lead to an increase in unhealthy behaviour among fire-fighting shift workers.

However, despite similar shift circumstances, such reported behaviour was not noticed due to a shorter observation period of the study. The researcher found that cooks' jobs at hotels occur in shifts that usually began early in the morning, although split shift was not a common occurrence. In Table 7.6 (page 159), almost 66 % of the kitchen workers had day shift and worked full-time. Professional cooks spend longer time in multi-station kitchens, especially since the working hours are often irregular (Marć *et al*. 2018: 2071). The work hours of sampled workers varied from five hours/day for part-time workers to a maximum 13-hour shift, sometimes daily in the current study. The shift of the workers affects their heat exposure (Flouris *et al.* 2018: 521).

The cross-tabulation between the kitchen worker's shift and BMI in the present study was found to be statistically significant, with the two-sided p-value from Fisher's Exact test at 0.033 (Table 7.6). Seventy percent (70 %) of the workers had higher weight than considered normal; 35 % were overweight, and another 35 % were obese.

Table 7.6 Kitchen worker shift

Shift	Tenure	Full-time	Part-time	Total
Day shift	Count	112	2	114
	% within Shift	97.4 %	2.6 %	100.0 %
	% within Tenure	67.5 %	60.0 %	67.3 %
	% of Total	65.5 %	1.8 %	67.3 %
Split shift	Count	1	0	1
	% within Shift	100.0 %	0.0 %	100.0 %
	% within Tenure	0.6 %	0.0 %	0.6 %
	% of Total	0.6 %	0.0 %	0.6 %
Evening shift	Count	22	1	23
	% within Shift	95.7 %	4.3 %	100.0 %
	% within Tenure	13.3 %	20.0 %	13.5 %
	% of Total	12.9 %	0.6%	13.5 %
Any other	Count	31	1	32
	% within Shift	96.9%	3.1 %	100.0 %
	% within Tenure	18.7 %	20.0 %	18.7 %
	% of Total	18.1 %	0.6 %	18.7 %
Total	Count	166	4	170
	% within Shift	97.1 %	2.9 %	100.0 %
	% within Tenure	100.0 %	100.0 %	100.0 %
	% of Total	97.1 %	2.9 %	100.0 %

The finding concurs with the investigation of changes in body mass index (BMI) between different work schedules conducted by Buchvold *et al*. (2018: 251); the researchers found that night workers had more significant BMI gain compared to day workers; the BMI increased considerably among night workers compared to day workers. Hence, shift workers are more likely to undergo heat stress from obesity described earlier. Moreover, section 7.6.3 divulges by way of logistic regression that heat (°C) experienced by chefs near stoves is affected by shift work along with other variables. The shift work of a kitchen worker influences the ability to cope with heat in the kitchen.

7.3 Factors affecting coping with thermal strain

Beyond their individual influences, the combined influence of age, gender, race, body weight, fitness and work experience affect the kitchen worker's ability to cope with thermal strain. The association between these personal factors will be discussed in the sections that follow. Page (2019: 11) identifies that climate change and advances in equipment types have contributed to the increased heat in commercial kitchens.

7.3.1 Multiple Personal factors

Further to individual factors presented earlier, the combined effects of these factors in Table 7.7 (page 161) exist, comprising of work experience, body weight, gender, race and fitness. Farnell *et al*. (2008: 238) state that fitness level, body composition, age, gender and race influence an individual's ability to thermos-regulate. Ravindra (2015: 56) found that besides age and gender, diet and exercise have the maximum impact on thermal comfort. Head chefs believe that age (59 %), task experience (47 %), fitness (20.6 %) and body weight(14.7 %) are recognised as important in coping with heat.

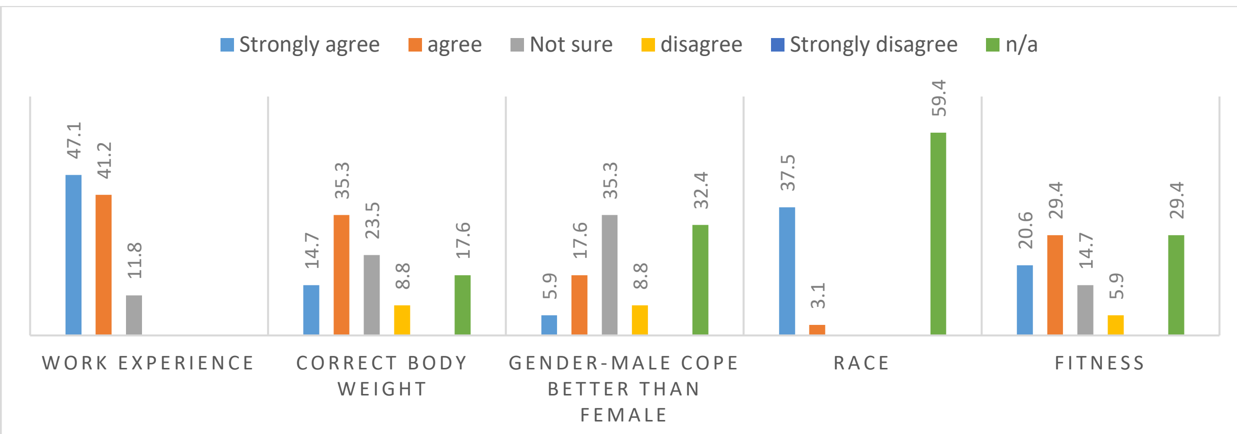


Figure 7.5 Factors affecting coping with kitchen heat

It seems that when multiple personal factors are given together, the final effect is much more than the simple algebraic sum of the magnitude of individual factors. A factor may decrease, oppose, reverse or counter the effect of a group of other factors or another factor. For instance, superb fitness may overcome the combined negative heat effects of no task experience, high body weight and gender.

The following patterns were observed in Figure 7.5:

- Some statements show significantly higher levels of agreement, for example, 47.1 % of head chefs and kitchen managers strongly agreed that work experience affects coping with heat whereas levels of disagreement seem zero. Similarly, 37.5 % strongly agree that the race of a worker influences coping with heat in the kitchen whilst the level of disagreement among head chefs seems zero.

- There are no statements indicating higher levels of disagreement, for example, only 8.8 % of head chefs and kitchen workers disagreed that body weight and gender influences coping with heat.

The significance of the differences is tested and shown in Table 7.7.

Table 7.7 Significant values of head chef's score

Factors	p- values
Age	0.002
Work experience	0.002
Correct body weight	0.016
Gender: male cope better than female	0.002
Race	0.000
Fitness	0.016

This indicated that the study resonates with the studies of Farnell *et al*. (2008: 238) and Ravindra (2015: 56) with respect to personal factors except gender. Chi-square test determined whether the scoring patterns per statement were significantly different per option. The results shown in Table 7.7 highlight that the significant p-value is less than 0.05; it implies that the distributions were not similar. That is, the differences between the way respondents scored agree, uncertain, or disagree were significant.

Tuomaala *et al*. (2013: 2310) proved that individual characteristics have an impact on thermal sensation. This is most likely due to individual body fat and muscle tissue ratios which greatly impact on gender and individual fitness and thermal sensation. However, the author could not demonstrate the combined effect of these individual factors (Table 7.7). Similarly, the current study did not find any correlation or association of significance from the combined effect of individual factors on thermal comfort.

7.3.2 Individual personal factors

Exploratory factor analysis (EFA) was conducted to obtain deeper insight into the individual factors that impact on heat stress. Acceptable loadings were revealed along two components with sub themes of Socio-economic Index and Demographics Rotated Component Matrix in Table 7.8 (page 162).

Using exploratory factor analysis, the questionnaire revealed a factor loading of 0.801, 0.400 and 0.672 for age, work experience and correct body weight with factors influencing coping with kitchen heat and was categorised into component 2, Socio-economic Index. Common magnitudes in the social sciences are low to moderate communalities of .40 to .70 (Costello and Osborne 2005:4). These variables triangulate favourably with Question 2, 4, 7, 35 and 36 from the interview schedule. Here, thirty-five percent (35 %) (f=12) of the head chefs strongly agreed that age has the highest level of influence on coping with kitchen heat; more than 47 % (f=16) strongly agreed that work experience and only 14.7 % (f=5) strongly agreed that correct body weight has the highest level of influence on coping with kitchen heat.

Table 7.8 Rotated Component Matrix: influence of factors on coping with heat

Personal factors	**Component**	
	1 Demographics	2 Socio-economic Index
Age	-0.007	0.801
Longer work experience	-0.352	0.400
Correct body weight	0.328	0.672
Gender male cope better than female	0.780	0.158
Race	0.850	-0.088
Fitness	0.554	0.426
Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.		
a. Rotation converged in 3 iterations.		

EFA further revealed a factor loading of 0.780, 0.850 and 0.554 for gender, race and fitness with factors influencing coping with kitchen heat and was categorised into component 1, Demographics. Contrarily, Figure 7.5 indicates that less than 6% (f=2) of head chefs strongly agreed that males cope better than females with kitchen heat. Consistent with EFA, 37.5 % (f=12) strongly agreed that race has the highest level of influence on coping with kitchen heat and 20.6 % (f=7) strongly agreed that fitness has the highest level of influence on coping with kitchen heat.

7.3.3 Association between personal factors

Logistic regression is used to obtain an odds ratio in the presence of more than one explanatory variable. Although the response variable is binomial, the result is the impact of each variable on the odds ratio of the observed event of interest. The main advantage is to avoid confounding effects by analysing the association of all variables together (Sperandei 2014: 12).

Table 7.9 Association between demographics

Variables in the Equation	**B**	**S.E.**	**Wald**	**df**	**Sig.**	**Exp(B)**	**95% C.I.for Exp(B)**	
							Lower	Upper
Work experience	-0.235	0.590	0.159	1	0.690	0.791	0.249	2.512
Correct body weight	-0.090	0.259	0.122	1	0.727	0.914	0.550	1.517
Gender male cope better than female	0.414	0.307	1.819	1	0.177	1.513	0.829	2.762
Race	-0.146	0.223	0.429	1	0.513	0.864	0.557	1.339
Fitness	0.375	0.237	2.504	1	0.114	**1.455**	0.914	2.315
Constant	-2.024	1.599	1.603	1	0.205	0.132		
a. Variable(s) entered on step 1: work experience, correct body weight, gender male cope better than female, race, fitness.								

Predicted Probability is of membership for female. The odds ratio is almost 1.5 and therefore, positive. Haruyama *et al.* (2010: 142), report an odds ratio of 1.0 and 0.94 for the association of subjective judgement scales (SJS) with BMI < 25.0 and ≥ 25.0, respectively. Each female worker assumes she is 1.45 times physically fitter than she actually is, which helps the female worker to cope with heat better as this has a positive psychological effect (Table 7.9). This odds ratio between predict factors that affect coping with heat in kitchens and female worker helps with prediction quality to achieve Objective 3.

Regarding physical fitness, 57%, 50%, 49% and 39% of the Black, Asian, Mixed-race (Coloured) and White respondents respectively, showed low physical fitness levels indicating lowered tolerance to heat. However, 10 %, 6 % and 5 % of the White, Asian/Black and Mixed-race (Coloured) respondents respectively, indicate a higher level of physical fitness indicating higher tolerance to heat.

This high prevalence of physical inactivity and unfitness may lead to various health problems (Smit *et al.* 2011: 450). The prevalence of obesity amongst Black urban SA adult women is disproportionately high and exceeds that of all other ethnic groups. This implies a lower thermal adaptation. This may, in part, be explained by the high prevalence of physical inactivity in this population group (Dickie 2013: 39). This means that the tendency of African women in Africa and elsewhere towards fitness is low due to various reasons including self-assumptions, physical inactivity and cultural expectations.

The association between BMI and fitness helps to determine the adaptability of local food production worker genotypes and phenotypes. The influence of kitchen workers' individual factors to selected indoor environmental quality (IEQ) conditions is contained in detail in Table 7.10. Montazami and Lunn (2020: 826) report that females are more affected by poor IEQ than males.

Table 7.10 Partial Eta Squared: physical fitness and BMI

Tests of Between-Subjects Effects						
Dependent Variable:						
Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
A7*A36	398.588	1	398.588	13.669	0.000	0.075
a. R Squared = .075 (Adjusted R Squared = .070)						

In response to the respondent's perception of their own physical fitness, their BMI statistic was appraised using partial eta squared per (Hillis 2018:1). Table 7.9 (page 163) indicates that physical fitness has a medium to large effect on BMI with p=0.075, a moderate effect from 0.06.

Concerning kitchen worker BMI, **s**trong links per Table 7.10 were found to exist in Table 7.11 (page 164) between:

- Gender, height and BMI. Since p= 0.046; less than the significance level of 0.05, strong evidence to conclude that the variables are associated.
- Gender and years of employment. Since p= 0.046; less than the significance level of 0.05, strong evidence to conclude that the variables are associated.
- Gender and type of kitchen. Since p= 0.046; less than the significance level of 0.05, strong evidence to conclude that the variables are associated.

Tests of between-subjects effects indicate that type of kitchen refers to heat load and extraction requirements. Higher heat loads require BMI in the normal range that helps with greater heat adaptation.

The literature demonstrates that the BMI of a kitchen worker is a significant predictor of the perceived effect of kitchen heat (Lisman *et al*. 2014: 1339 and Tuomaala *et al*. 2013: 2309). Sadiq *et al*. (2019: 4) reported a significant multiple linear regression for the variables: WBGT, BMI, age and gender. It is therefore necessary that BMI determination is further explored [$Y = b0 + b1*x1 + b2*x2 + b3*x3$].

Hence, BMI = 3.475 + (0.584 x type of kitchen) + (3.257 x gender) + (0.296 x weight of the staff). The analysis in Table 7.12 (page 166) is likely to reveal measures that may be undertaken to manage heat stress in commercial kitchens better.

Table 7.11 Factors affecting BMI of a kitchen worker

Coefficients[a]								
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	3.475	2.288		1.518	0.131		
	Type of Kitchen 4	0.584	0.287	0.082	2.034	**0.044**	0.832	1.202
	Gender of staff A3	3.257	0.470	0.279	6.938	**0.000**	0.827	1.209
	Weight of worker A6	0.296	0.013	0.817	21.948	**0.000**	0.966	1.035
	Race A4	0.655	0.364	0.068	1.801	0.074	0.953	1.050
	Working hours A11	-0.167	0.108	-0.059	-1.548	0.124	0.918	1.090
	Tenure A10	-2.232	1.221	-0.069	-1.828	0.070	0.927	1.079
	Shift A13	-0.282	0.173	-0.061	-1.633	0.105	0.948	1.055

a. Dependent Variable: BMI (Kg/m²) of kitchen worker A7

b. Predictors: (Constant), Shift, Gender, Weight, Working hours, Race, Tenure, Type of kitchen

Tests for multi-collinearity in Table 7.11 indicated the presence of a very low level of multi-collinearity (VIF = 1.202 for type of Kitchen, VIF = 1.209 for gender and VIF = 1.035 for weight). The type of kitchen was the first variable entered, followed by gender and weight of kitchen worker according to theory. Results of the regression analysis provided beta coefficients for three predictors: BMI and type of kitchen, $\beta = 0.584$, $t = 2.034$, $p < 0.044$; gender $\beta = 3.257$, $t = 6.938$, $p < 0.00$ and weight of kitchen worker $\beta = 0.296$, $t = 21.948$, $p < 0.00$. The best fitting model for predicting BMI of the kitchen staff is a linear combination of the type of kitchen, gender of staff and weight of worker. The preceding section of this chapter has presented the role of gender, and weight in perception of heat stress and discomfort.

7.4 Heat production in kitchen

The kitchen activities, as well as cuisine, affect the kitchen equipment utilised and subsequent heat production. Every active zone in the kitchen workspace holds a subset of equipment appropriate for the associated activity for that work area. The presence of a large number of appliances for meal preparation such as grills, ovens, hot plates, fryers, kettles and pasta boilers in commercial kitchens causes a significant increase in temperature (Marć *et al.* 2018: 2071).

7.4.1 Kitchen activities

Pehkonen *et al.* (2008: 115) reports that a kitchen worker prepares a wide range of foods routinely. Preparation of food for a large number of consumers within a predetermined time causes huge workload and pressure to the kitchen workers (Gigstad 2002: 1). Ramesh and Manikandan (2015: 473) acknowledge that the restaurant industry requires large quantities of food.

Table 7.12 Factor Analysis of kitchen equipment

Equipment	Component
	1 Large Appliance
Ovens	0.761
Boilers and steamers	0.883
Gas stoves	0.897
Fryers	0.761

The heat emission from cooking equipment includes oven, stove, griller, fryer and tandoor. Exploratory factor analysis in Table 7.12 reveals that the four main kitchen equipment fit into a single loading of component 1, Large Appliance that impact on heat production. This is a simple structure, a pattern of results, such that each variable loads highly onto one and **only one factor** (UCLA: Statistical Consulting Group 2021: 1). The effect on the human physiology from the use of each of the cooking equipment is discussed in 2.11.1 and 4.3.1.

7.4.2 Food production system

The cook-serve method was found to be very popular in the sampled kitchens; the conventional food service system is the most common production method. Eighty-eight percent (88 %) of kitchens prepared main courses on customers' orders. Section 7.5 discusses the heat discomfort aspects related to design elements of kitchens. Unlike cook-serve preparation used in the past, a variety of technologically advanced cooking options are available to large-scale operators (Rodgers and Assaf 2007: 40) that can assist in lower heat production during peak periods.

The cook-chill system is observed in three commissary kitchens in this study. When the cook-chill system is followed instead of cook-serve, the two variables 'number of meals per day' and 'heat near stoves' are negatively associated. The food is cooked in advance to service and kept frozen/chilled until service. The coefficient for output of meals (-0.829) is significantly different from 0 because its p-value is 0.036. The variables 'number of meals' and 'heat experienced near stoves' are closely associated. The greater the number of meals, the greater the heat in the kitchen if the cook-serve system is followed as many more meals are prepared in commercial kitchens (Marć *et al*. 2018: 2071). However, most preparation work involves cooking in advance or semi-prepared meals for quicker service. Full meals cooked in advance can be refrigerated and reheated at service time (Petre 2018: 1). The author also recommends prepping the ingredients required for specific meals ahead of time to cut down on cooking time in the kitchen. Cook-chill systems are used by many types of food service organisations including fine dining restaurants (Plascon 2020: 1).

As given in the equation in section 7.4.2, the greater the number of meals, the less heat as food is cooked unhurried well ahead of serving time. So, for every unit increase in meals, a 0.829 unit decrease in heat experience near the stove area value is predicted, holding all other variables constant, provided the method of cook-serve is not followed. This p-value indicates that the observed difference of more than 3.6 % in studies would be observed due to random sampling error. Further details are described in the following sections.

7.4.3 Kitchen output affects heat production

The number of meals cooked per day (Figure 7.5) indirectly allude to the equipment heat generation that indicates the heat produced in the kitchen. The larger the volume of food cooked, the greater the amount of heat produced in cook-serve. However, no absolute value of temperatures across the spectrum was measured.

There were significantly more respondents who indicated that they served less than 250 meals per day (76.5 %) ($p = 0.004$). Welch (2017: 14) reports that higher production kitchens had a significantly greater increase in heat index compared to low production take away kitchens in Florida. Logeswari and Mrunalini (2017: 609) report that workers in university hostel kitchens prepared 200 meals for breakfast, lunch and supper. Large kitchens 6, 7 and 14 prepared meals ranging from 50 meals an hour to 400 meals a shift including sit-down, room service and takeaway.

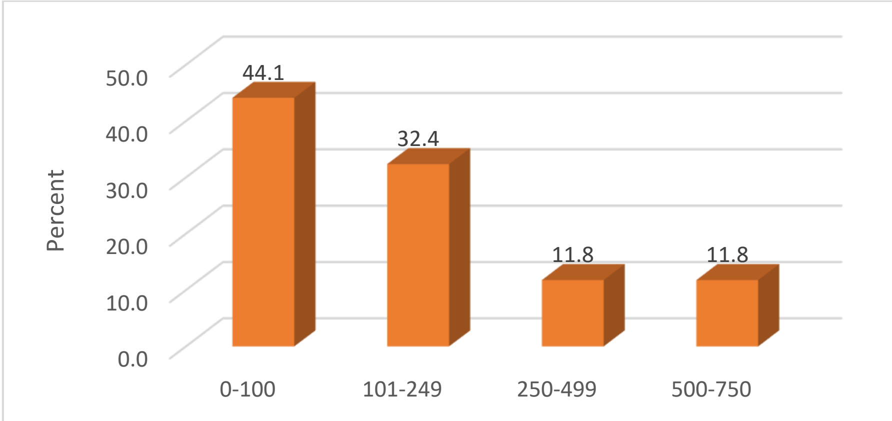


Figure 7.6 Number of meals per day

Seventy percent (70 %) of the kitchen workers claimed that food preparation produces heat and kitchens are hot (Figure 7.8 and Figure 7.9) and 75 % claimed that the kitchens were extremely hot during maximum kitchen capacity utilisation where volume is highest. Likewise, Logeswari and Mrinalini (2017: 607) reported that relatively higher eat on the surface and surroundings is emitted when large quantities of food are cooked.

Figure 7.9 describes the sampled kitchen during peak hours. More than 80 % of the respondents indicated that it was hot during peak hours ($p < 0.001$). Only 3 % indicated that the kitchen was slightly warm as they adopted a ready-prepared system. The thermal environment is affected by the type of kitchen load and type of food production system (Li and Kosonen 2020: 151) as indicated in Figure 7.8 and 7.9.

For temperature control in kitchen, Laikko-Roto and Nevas (2014: 67) reported that the scores obtained were 9.5 (55/56) and 9.5 (82/82); p =¼ 0.000* with the food control officials and restaurant owners, respectively.

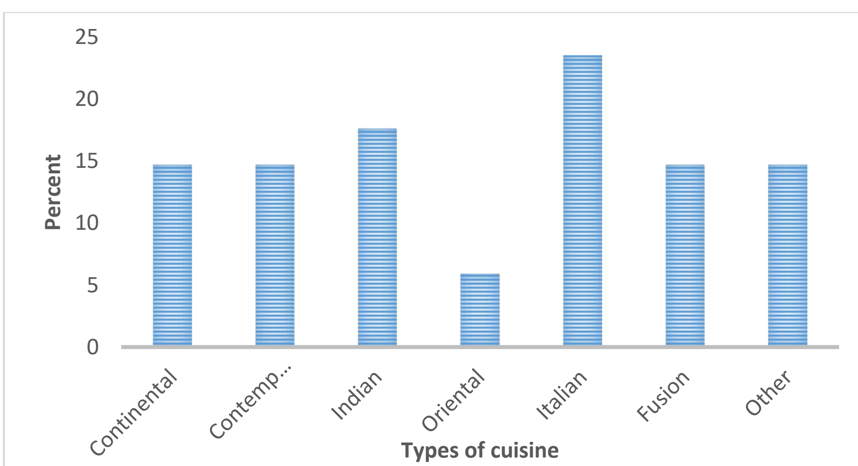


Figure 7.7 Dominant cuisines in Durban in the primary study

7.4.4 Diverse cuisine

A diverse range of cuisine is offered in the sampled kitchens from Indian to Mexican, especially Italian. Two restaurants served seafood and authentic Indian; South African Indian cuisine was observed in three kitchens (Figure 7.6). Indian cuisine kitchens had higher temperatures in receiving areas (29.82 °C) due to the lack of back doors. The researcher contends that greater the food processing, for example, in Indian cuisine, greater the extent of the cooking process, and higher the heat generated. Heavy preparation activities also lead to excessive dishes to be washed that increases humidity.

Different styles of cooking operation make a significant contribution to heat in commercial kitchens. Italian food was served at more establishments in the sample frame than any other (23.5 %), ranging from pizzas only to a wide variety of pasta and antipasti (Figure 7.7). Italian cuisine kitchens have brick kilns that increase operative temperature near ovens (31.4 °C).

Table 7.16 (page 173) sums up the temperatures due to various cuisines. There were similar levels amongst the other offerings, with oriental being the lowest (5.9 %). The maximum mean operative temperature was from grilling in kitchens producing fast-foods; higher heat emitting open flame grilled food is preferred over flattop grill due to smoky flavours. Moreover, constant frying, especially French fries or chips, fish or chicken, raises the temperature near fryers.

7.4.4.1 Asian cooking is extra-heavy load

Kosonen (2014: 2) claims that European cooking is medium load, whereas Asian cooking is extra-heavy load. Conversely, IMC and ASHRAE categorise kitchens as extra-heavy load only if solid fuels are used. The author adds that radiated heat cannot be removed with the extraction system. Table 7.16 (page 173) indicates that cooking area in an oriental kitchen has a high temperature from wok cooking (315 °C) as per Lin and Liou (2000: 817) and hence considered as being extra-heavy-duty with higher CO_2 emissions (1000 ppm) as per Jiang *et al*. (2012: 4435); similar to pizza ovens in Italian kitchens.

7.4.4.2 Increased heat from extra-heavy-duty load

Extra-heavy-duty equipment cook at higher temperatures and produce radiant heat as experienced by workers near traditional kilns and tandoors (Table 7.13 page 170**)**. Extra-heavy-duty kitchens operate at higher temperatures with higher extraction capacity due to solid fuels. Nearly 55 % of kitchen workers experienced radiant heat from old-style ovens such as wood-fired pizza kilns (371 °C) and tandoor (480 °C) and heat is high in kitchens using gas and solid fuels compared to electricity as indicated in Figure 7.7. Grillers experienced higher mean temperatures of 33.75 °C that resonates with Wong *et al*. (2011: 747).

Table 7.13 Mean temperatures of kitchens as per ASHRAE classification

Operative Temperature in °C	Light-duty	Medium-duty	Heavy-duty	Extra-heavy-duty
Stove	0	26.44	26.54	30.66
Oven-electric, gas, kiln and tandoor	30.75	28.03	30.28	31.15
Griller	0	32.11	**33.75**	32.25
Fryer	0	30.07	30.92	32.20

The sampled kitchens indicate that frying cooks were also heat exposed with temperatures of 32.20 °C. Exposure to the stove or heat was much higher for workers responsible for cooking and food preparation than for auxiliary staff. Significantly more kitchen workers experience heat ($p < 0.001$).

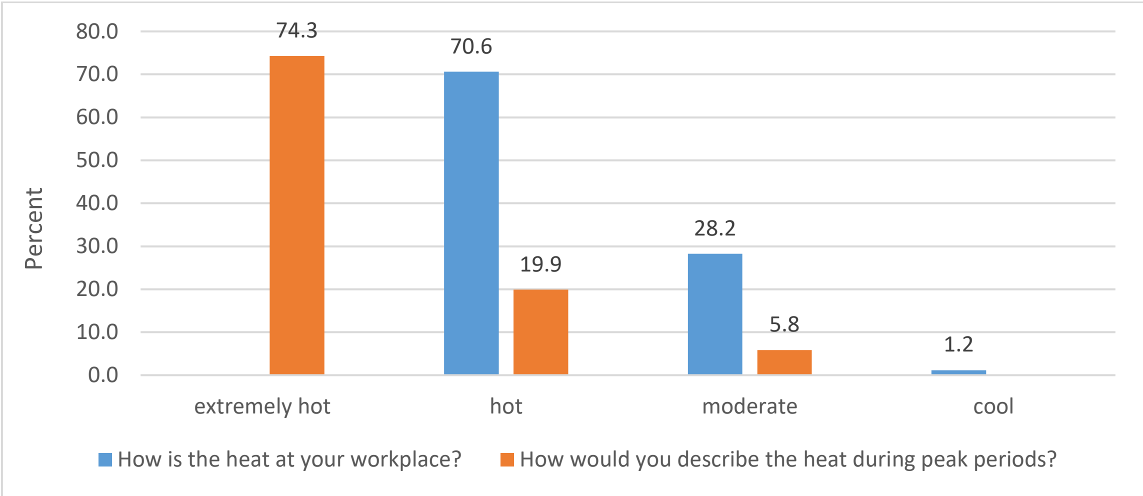


Figure 7.8 Food service workers' opinion on heat in kitchens

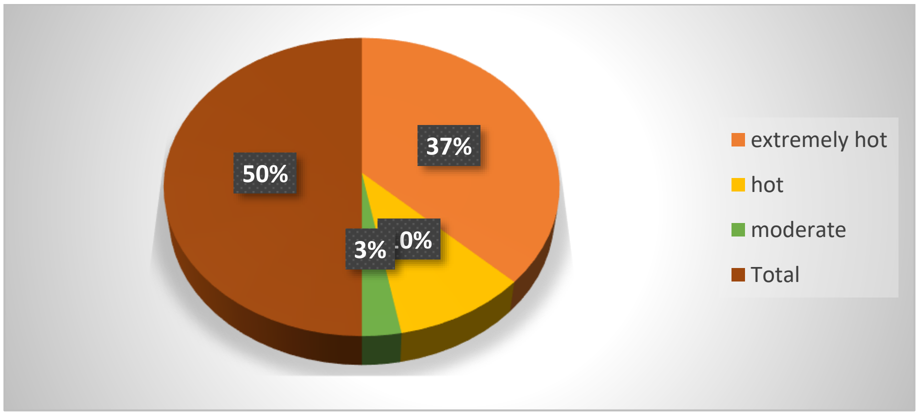


Figure 7.9 Heat during peak hours in kitchen as per food service workers

7.5 Design elements of kitchens

The plurality of kitchen activities comprises of baking, cooking, preparation and clean up. The sections that follow will encompass type of fuel and classification of kitchens.

7.5.1 Fuels in the kitchen

The current study surveyed light-duty-2, medium-duty-5, heavy-duty-20 and extra-heavy-duty-6. In this study context, type of fuel and equipment in kitchen denotes the load in kitchen in terms of ventilation requirements. Section 4.2.3 reviews how this typology of kitchen influences heat emission.

Liquid petroleum gas (LPG) and solid fuels generate extreme cooking temperatures as they cook at temperatures of 371 °C to 480 °C as per Shah (2013: 1). Among the 33 sampled kitchens, 31 kitchens had both electrical equipment and gas appliances. Twelve percent (12 %) kitchens used firewood, in addition to LPG and electricity, and 6 % used charcoal for baking and grilling. Two kitchens producing authentic Indian cuisine had tandoor ovens that used LPG and charcoal. Singh *et al.* (2016: 8) report that with LPG stoves cooking Indian cuisine have temperatures soared to 38 °C with RH of 66.7 %. Five of the seven kitchens that cooked Italian cuisine had wood-fired kilns; one used an LPG fired kiln/tunnel oven and two restaurants used electric ovens as well. Oriental cuisine prepares most of the food in a wok cooked with LPG under pressure at higher temperatures (Jiang *et al*. 2012: 4435). Matsuzuki (2011: 608) recorded WBGT of 22.9 °C to 27.4 °C in LPG kitchens in Japan.

Wong *et al.* (2011: 747) state that Chinese restaurants traditionally cook with an LPG flame. Everyday Health (2017: 1) indicates that the cooks prefer the instant heat of LPG stoves. Gas stoves offer quick control of heat transfer. Table 7.14 indicates the preference for gas as a fuel that contributes to higher ambient temperature in sampled kitchens.

Table 7.14 Kitchen workers' preference for cooking fuel

Fuel	Frequency	Percent
Gas	69	58.5
Electric	49	41.5
Total	118	100.0

The researcher suggests that instancy may be associated with a comfortable lifestyle. Notably, the cross-tabulation between the kitchen worker's preference for LPG stove or electric stove and maintaining a comfortable lifestyle was found to be statistically significant, (n=33), $p < .011$, two-tailed. Just over 58.5% and 41.0 % of the workers felt comfortable cooking with LPG and electric stove, respectively. LPG beats electric if one wants searing heat and exact temperatures immediately. Although cooks claim that LPG cooks more evenly, gas is the least efficient fuel source at heat transference; up to 60 % of the heat produced by a gas burner is wasted as it escapes into the air (Joachim and Schloss 2017: 4). Almost 74 % of the energy produced on an electric stove is transferred to food, compared to about 40 % percent on a gas range (Schwartz and Vila 2020: 3).

Table 7.15 Heat experienced by chefs using gas and electricity

Kitchen No.	Kitchen worker/chef	Frequency	Electric equipment	Gas equipment	Sweating	Red face	Heavy sweating
5, 9, 26	Grill chef	3	Griller		✓		
8,13, 22, 27	Grill chef	6		Griller	✓		
21	Teppanyaki chef	1		Teppanyaki	✓	✓	
16	Roti chef	1		Griddle	✓		
23	Curry chef	1		Stove	✓	✓	
16	Curry chef	1		Pressure stove			✓
16	Tandoori chef	1		Tandoor	✓		
17	Head chef	1		Wok	✓		
28	Pizza chef	1		Pizza oven	✓		
15, 31	Pizza chef	2	Pizza oven		✓		
13, 26	Fry chef	2	Fryer		✓		
6	Fry chef	1	Pressure fryer		✓		
20	Chef de partie	1		Stove	✓		
14	Breakfast chef	1	Toaster		✓		
	Total	23	8	15	23	2	1
	Percent	70 %	28 %	54 %	84 %	67 %	100 %

A comparison of gas and electrically fuelled cooking equipment revealed that the experience of heat is higher in kitchens using gas fuels compared to electricity (Table 7.15). The adoption of gas and electrically fuelled cooking equipment were 28 % and 54 % respectively in 31 kitchens. Grillers, resembling measures by Wong *et al.* (2011: 747), experienced high temperatures of 33.75 °C. To a lesser extent, the sampled frying cooks using electricity were also heat exposed to mean temperatures of 32.20 °C. Sweating and red-faced pointers to heat stress were generally indicated in gas-fuelled kitchens, especially at the stove ranges Teppanyaki and pressure stove.

7.5.2 Effect of cooking equipment

Type and size of cooking equipment affects the heat generated in the kitchen (Mealey 2018: 1). The menu does not necessarily need the presence of stoves in kitchens as cooking methods have changed. It was observed in the current study that two pizzerias cooked exclusively on a conveyor oven and did not produce high heat and accordingly classified as light-duty. Matsuzuki (2008: 363, 367) report that the time required for heating did not significantly differ between the induction heat (IH) stove (63.5 ± 10.1 min) and the LPG stove (59.0 ± 7.0 min).

Table 7.16 Operative temperatures and cuisines

Kitchen areas	Fusion	European (Continental)	Contemporary	Fast-food	Oriental	Indian	Italian
Receiving	25.14	25.8	27.85	29.38	27.3	**29.82**	28.21
Preparation area	27.56	25.8	30	30.08	**30.85**	29.22	29.7
Stove	29.18	27.6	26.76	29	**30.85**	30.82	30.08
Oven	27.85	27.15	28.05	30.75	-	31.03	**31.41**
Dishwashing	26.62	29.7	28.4	29.3	28.8	**29.68**	30.31
Griller	31.8	31	31.86	**33.86**	-	-	28
Fryer	27.7	-	30.6	**31.2**	31.1	26.8	-

However, the authors report that all heat parameters were significantly higher in kitchens using the LPG stove than using the IH stove. The IH stove which provided a better work environment; therefore, the electrified kitchen is preferable as a comfortable work environment for workers. The heavy-duty kitchen mean temperatures per Table 7.17 near grillers were higher than medium and extra-heavy-duty kitchens. Possibly due to the substantial use of LPG appliances contributing to expected higher values. The finding of the current study concurs that equipment classified as extra-heavy load due to the use of solid fuels such as charcoal in tandoors had an operative temperature of 32 °C compared to wood-fired pizza kilns with a temperature range from 29 °C to 34 °C. Electric conveyor ovens, however, measured from 28 °C to 33 °C.

Table 7.17 Mean temperatures in kitchen areas

Areas	**Mean**	**Median**	**N**	**Std. Deviation**	**Minimum**	**Maximum**	**Range**
Receiving	27.78	27.80	30	2.55	21.90	31.90	10.00
Preparation	28.97	29.40	32	2.52	23.10	33.70	10.60
Stove	30.71	30.80	31	3.19	23.20	38.00	14.80
Oven	30.81	30.90	30	2.69	24.80	38.20	13.40
Holding	29.73	29.70	33	2.41	23.10	34.40	11.30
Dishwashing	28.96	29.00	33	1.86	24.90	33.60	8.70

Generally, the findings of mean temperature in Table 7.17 aligns with Matsuzuki *et al*. (2011: 605) in respect of stoves and ovens. However, in respect of fryers, the range differs by approximately 4 °C.

This difference may be attributed to cuisine and peak periods. The factors affecting the heat experienced by kitchen workers near stoves vary. Primary factors revealed in statistical analysis were the kitchen height, symptoms face-red, sweating, discomfort index, staff/space ratio and state of the uniform.

Table 7.18 Factors affecting heat near cooking stoves

Coefficients[a]								
Model		Unstandardised Coefficients		Standardised Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	-6.795	5.720		-1.188	0.250		
	Height of kitchens (m)	-0.429	0.518	-0.077	-0.828	0.418	0.784	1.276
	Symptoms face-red	-2.162	0.773	-0.246	-2.796	**0.012**	0.877	1.141
	Sweating	-0.515	0.520	-0.089	-0.991	0.334	0.837	1.195
	Discomfort Index (Stove/Oven)	0.446	0.041	0.955	10.920	**0.000**	0.887	1.127
	Staff /space ratio (workspace ratio)	0.016	0.052	0.026	0.300	0.767	0.872	1.146
	Uniform is wet-excessive sweating	-1.424	1.299	-0.097	-1.096	0.287	0.857	1.167

a. Dependent Variable: heat near stove

b. Predictors: (Constant), width, length, height of kitchens, Staff / Space ratio, Symptoms: Face-red, sweating, Uniform is wet-excessive sweating, Number of Fans, Discomfort Index (Stove / Oven)

The regression Y = b0 +b1 * X1 +b2*x2 revealed heat near stove = – 6.795 + (– 2.162 x symptoms red face) + (0.446 x Discomfort Index) per Table 7.18.

Tests for multi-collinearity indicated that a very low level (VIF = 1.141 for symptoms face-red and 1.127 for discomfort index (Stove/Oven). Beta coefficients for the two predictors were heat near stove and symptoms face-red, $\beta = -2.162$, $t = -2.796$, $p < 0.012$ discomfort index, $\beta = 0.446$, $t = 10.920$, $p < 0.00$. The best fitting model for predicting heat near the stove is a linear combination of symptoms of face is red among kitchen workers and discomfort index (due to heat from stove or oven). Other predictors were not significant in the mathematical model given above in Table 7.18.

7.5.3 Heat (°C) near stoves is affected by other appliances

Other equipment, in addition to stoves such as ovens and dishwashers, also contribute to heat in the kitchen.

Y = b0 + b1x1

Heat = 17.078 + (0.312 x oven heat)

Since the variable heat from dishwashing unit was not significant, it cannot be a part of the mathematical model here. As per section 4.3.1, Type II hoods are installed above dishwashers as they are light-duty appliances due to lower heat loads.

Table 7.19 Heat near stoves affected by ovens and dishwashers

Coefficients[a]								
Model		Unstandardised Coefficients		Standardised Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	0.235	6.757		0.035	0.973		
	Heat from Oven DA97.4	0.882	0.133	0.774	6.651	**0.000**	0.993	1.007
	Dishwashing heat DA97.6	0.108	0.197	0.063	0.545	0.590	0.993	1.007
a. Dependent Variable: Heat near stoves DA97.3								

Tests for multi-collinearity indicated that a very low level was present namely, VIF = 1.007 for heat from the oven and VIF = 1.007 for heat from the dishwasher. Beta coefficients for the two predictors were heat from oven, $\beta = 0.882$, $t = 6.651$, $p < 0.00$; dishwashing heat $\beta = 0.108$, $t = 0.545$, $p < 0.590$. The best fitting model for predicting heat from ovens is a linear combination of heat from the oven (Table 7.19).

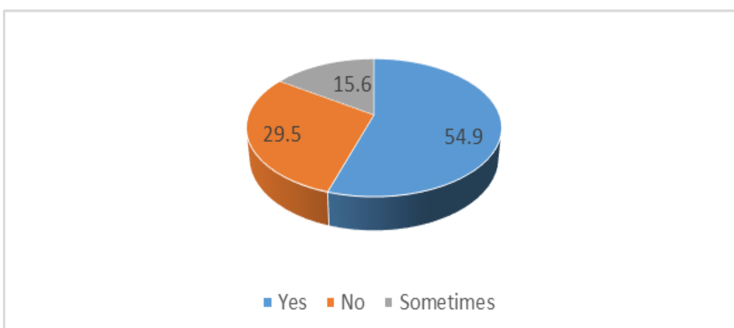


Figure 7.10 Radiant heat experienced when cooking with traditional clay ovens

7.6 Heat stress

The cooking of food, cooking methods and higher humidity levels increase heat stress among kitchen workers (Matsuzuki *et al*. 2011: 605). Commercial kitchens range from tiny, independent locally owned restaurants to the high-volume production environments of convention centres and institutions

(Decker 2018: 1). Logeswari and Mrunalini (2017: 609) report on heat stress among hostel food service workers. Kitchens with high heat and humidity contribute to heat-related illnesses among workers who spend long hours under these stressful conditions (Singh *et al*. 2016: 4). Indian cooks in the kitchen faced discomfort caused by high volume and frequency of various meals (Subramaniam and Murugesan 2015: 529). The sections that will follow compare and evaluate heat variables and chef experience of heat near stoves.

7.6.1 Comparison of heat variables observed by various researchers

Whilst heat as indicated in 7.6.1 is an essential determinant of the method and technique of its management, Saha *et al*. (2012: 181) found commercial kitchen heat managed between 25 °C to 38 °C. Additionally, Simone *et al*. (2013: 1008) found that the kitchen work area temperature variations were from 22.5 °C near dishwashing to 28.1 °C near the cooking area. The data in Table 7.17 (page 173) point to a wide variation from 19.8 °C to 31.3 °C.

Table 7.20 Comparative study of operative temperatures (°C) by different investigators

Type of Kitchens	Zones/areas	**Current study** 2019	Simone *et al*. (2013: 1007)	Saha *et al*. (2012: 183)	Li *et al*. (2012)	
Casual	Cooking	29.29	31.3		23.5	Kitchen 1
	Preparation	28.13	23.9		19.6	
	Dish washing	27.00	21.8		19.6	
Institutional	Cooking	29.37	30.9		24.8	Kitchen 2
	Preparation	27.91	23.6		24.0	
	Dish washing	28.00	24.8		23.7	
QSR	Cooking	30.50	26.3		34.7	Kitchen 3
	Preparation	30.72	25.9		23.7	
	Dish washing	30.92	19.8		22.8	
Kitchen 1				34.0	53.0	Kitchen 4
Kitchen 2				36.0	30.8	
Kitchen 3				38.0	32.0	
Kitchen 4				25.0		

Measuring a commercial kitchen environment during the peak time of operation provides a better mean value (Simone *et al*. 2013: 1005). The cookers in the present study comprised of grillers, ovens, fryers and cooking stoves. The measuring instrument was directed at cookers and measured consecutively every minute while maintaining a relative position at the cooking side. The ambient temperature of working areas was measured with a heat stress meter. The mean values obtained in the study are comparable with similar studies as indicated in Table 7.20.

The temperature near stoves at the height of one metre varied from 23 °C to 34.6 °C, while the temperature near ovens ranged from 24.8 °C to 33.8 °C. Griller areas recorded the highest temperatures from 30.1 °C to 34 °C. Areas near fryers logged operative temperatures from 26.6 °C to 32 °C. Such detailed measures of temperatures in kitchens have not been documented in similar studies. However, it is essential to note that all kitchens sampled do not all use the same equipment. Notwithstanding, the values recorded are comparable to the findings by Simone *et al*. (2013: 1008).

Among the different types of food service establishments, casual service in the current study showed the highest temperature in the cooking zone, followed by institutional food service. Dishwashing zones tend to have higher values due to higher humidity levels compared to preparation areas.

Workers are exposed to heat in many workplaces, including kitchens (Zare *et al.* 2019: 1). Welch (2017: 8) documented WBGT ranging from 26.5 °C to 38.9 °C in commercial kitchens. The sampled kitchens recorded lower maximum temperatures than Welch (2017: 8) however, resonates with Simone *et al*. (2013: 1008) who logged 24.2 °C to 34.5 °C as WBGT (Table 7.21). Higher globe temperatures indicate high humidity values. Matsuzuki's *et al*. (2011: 605) study is a testimony to an average estimated ambient WBGTs less than 27.5 °C in front of cookers. Similar temperatures were recorded in preparation areas in the sampled institutional kitchens.

Table 7.21 Comparison of heat parameters with Simone *et al.* (2013: 1008)

Type of Kitchens	Zones/areas	Air temperature (°C) height - 01.1m	Globe temperature (°C)	Operative temperature (°C) **Current study** 2019	Globe temperature (°C) **Current study**
Casual	Cooking	32.6	34.5	**29.29**	**35.58**
	Preparation	27.4	27.8	**28.13**	**30.07**
	Dish washing	27.9	27.9	**27.00**	**28.97**
Institutional	Cooking	28.4	30.6	**29.37**	**34.13**
	Preparation	24.2	24.6	**27.91**	**27.13**
	Dish washing	24.8	25.2	**28.00**	**28.25**
QSR	Cooking	27.3	28.6	**30.92**	**33.56**
	Preparation	25.9	26.1	**30.72**	**30.85**
	Dish washing	23.9	24.2	**30.50**	**31.40**

7.6.2 Chef heat experience at stoves

Statement on kitchen heat by chefs was found to be associated with job position, work shift, type of kitchen load, years of employment and race. Except for grillers and bakers, the other chefs and kitchen workers were not stove, or heat exposed. The adoption of the equation Y = b0+ (- b1)*x1 + (- b2) *x2 + (– b3) *x3 + (– b4) *x4 indicates that secondary factors affecting heat perception near stove = 35.341 + (-0.103 x job position) + (-0.091 x years of employment) + (-0.403 x worker shift) + (-0.722 x type of kitchen).

Tests in Table 7.22 for multi-collinearity indicated that a very low level (VIF = 1.022 for job position, VIF = 1.005 for years of employment, VIF = 1.046 for worker shift and VIF = 1.033 for type of kitchen). Beta coefficients for five predictors were heat near stoves and job position, β = -0.103, t = -2.077, p < 0.039; years of employment β = -0.091, t = -2.016, p < 0.045; worker shift β = -0.403, t = - 2.276, p <0.24 and type of kitchen β = -0.722, t = -2.548, p = 0.012. The best fitting model for predicting heat near stoves is a linear combination of type of kitchen, job position, years of employment and worker shift.

The relationship with job position indicates that the higher the position, lower the heat experienced near stoves. There is strong evidence to conclude that the variables are negatively associated. With p=0.039; less than the significance level of 0.05, this p-value indicates that the observed difference in more than 3.9 % of studies would be observed due to random sampling error. For instance, years of employment with p=0.045, the observed difference of more than 4.5 % of studies would be observed due to random sampling error.

Table 7.22 Secondary factors affecting heat near stove

Coefficients[a]								
Model		**Unstandardized Coefficients**		**Standardized Coefficients**	**t**	**Sig.**	**Collinearity Statistics**	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	35.341	1.069		33.046	0.000		
	Job position A8	-0.103	0.049	-0.153	-2.077	**0.039**	0.978	1.022
	Years of employment A10	-0.091	0.045	-0.148	-2.016	**0.045**	0.995	1.005
	Worker shift A13	-0.403	0.177	-0.170	-2.276	**0.024**	0.956	1.046
	Type of kitchen 4	-0.722	0.283	-0.189	-2.548	**0.012**	0.968	1.033
	Race A4	-0.588	0.383	-0.113	-1.537	0.126	0.988	1.013
a. Dependent Variable: Heat near stoves								
b. Predictors: (Constant), Shift, Race, Years of employment, Job position, Type of kitchen								

7.6.3 Effect of humidity on kitchen temperatures

Higher levels of humidity during peak periods steered kitchens to being extremely hot. Thirty-nine percent (39 %) of the kitchen managers responded that humidity was high, more than 48 % indicated that staff complained about humidity (Appendix 14). The humidity values are comparatively higher in Durban's semi-tropical coastal climate. Increased humidity levels increased thermal strain, specifically in cooking and dishwashing areas. High discomfort index was accordingly observed in most kitchens (Table 7.24 page 180). The use of cooking equipment to its maximum capacity increased heat stress among more than 25 % of kitchen workers (Table 7.27 page 183).

7.6.3.1 Combined effect of temperature and humidity-WBGT

According to South African Weather Services (2020: 1), the WBGT index is the impact of heat stress on an individual and a combined effect of temperature and humidity. The European Agency for Safety and Health at Work (2008a: 71) confirm that high surrounding temperatures can lead to discomfort and even heat stress at a WGBT index of 26.8 °C. The WBGT in the sampled kitchens varied closely as indicated in Table 7.20 (page 176). Institutional kitchens recorded lowest mean WBGT (Table 7.23) near ovens (25.76 °C) and stoves (25.76 °C) which are slightly higher, the permissible limit of corrected effective temperature (CET) being 23.0 °C to 25.0 °C according to ILO regulations (Maruthi *et al.* 2013: 4). The author observed that the kitchen temperature ranges from 38 °C to 45 °C in the food parlours in India with humidity levels between 70 % and 80 %. Matsuzuki *et al.* (2011: 608) report WBGT of 24.5 °C and 25.3 °C respectively near ovens and stoves, closer to ILO regulation, however, Haruyama *et al*. (2010: 138) report 24.6 °C and 26.7 °C near ovens and stoves respectfully.

Table 7.23 WBGT values in sampled kitchens

Kitchen zones (° C)	Casual	Institutional	QSR
Preparation area	24.91	22.74	25.55
Stove	26.94	25.81	26.17
Oven	27.28	25.76	27.35
Griller	26.77	**30.4**	28.37
Fryer	26.11	28.4	30.16

The Department of Occupational Safety and Health (2016: 7), reported that the WBGT in confectioneries were 30.2 °C to 31.6 °C and workers should avoid discomfort from the heat. The guideline also elaborates on risk assessment and risk control. Ramesh and Manikandan (2015: 473) argue that the recommended RH level range from 40 % to 60 %. Providing ventilation by free draft/ forced draft will help to attain better RH.

7.6.3.2 Discomfort Index (DI) near stoves

Bradshaw (2006: 25) reveals that uneven radiation from hot and cold surfaces, temperature stratification in the air, a wide disparity between air temperature and radiant temperature, contact with a warm floor, and other factors can cause local discomfort and reduce the thermal acceptability level of the space. Although a person may feel thermally neutral in general, preferring neither a warmer nor a cooler environment, thermal discomfort may exist due to temperature gradient in the body.

Table 7.24 Discomfort index near stoves

Coefficients[a]								
Model		**Unstandardised Coefficients**		**Standardised Coefficients**	**t**	**Sig.**	**Collinearity Statistics**	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	49.152	10.718		4.586	0.000		
	Heat near stove DA97.3	2.013	0.397	0.686	5.074	0.000	1.000	1.000
a. Dependent Variable: Discomfort Index (Stove / Oven) DA105.3								

Alam *et al*. (2019: 2) investigated the cause and effect of discomfort while cooking due to the airflow variations in the railway pantry kitchen. Measurements indicated that only the cooking area presented dissatisfaction with thermal conditions, whereas 50 % of employees were dissatisfied in cooking and food preparation areas. Parrott *et al*. (2003: 1) claim that humidity is generated in a kitchen from cooking. Humidity can increase wetness on different areas of the body, leading to a perception of discomfort (Faizal *et al.* 2011: 5).

The discomfort index near the stove in the present study was modelled on the equation Y = b0 + b1x1, which indicates that the discomfort index near stove = 49.152 + (2.013 x heat near stoves). In Table 7.24, the coefficient for heat near stoves is 2.013. Thus, for every unit increase in heat near stoves, a 2.013 unit increase in discomfort index value is predicted, holding all other variables constant. The p-value is 0.00. The coefficient of heat near stoves is equal to zero. Tests for multi-collinearity indicated that a very low level (VIF = 1.00 for heat near stoves). Beta coefficients for the one predictor was, heat near stoves, $\beta = 2.013$, $t = 5.074$, $p < 0.000$. The best fitting model for predicting discomfort index near stoves is a linear combination of heat near stoves. The equation for heat near stoves assists in addressing study Objective 4 that seeks to compose indoor environmental criteria for commercial kitchen design.

7.6.3.3 Discomfort Index near humid areas

Humid areas measures were taken at positions near the minimum value > 85 indicates that the index is uncomfortable near stoves and dishwashers. The maximum values > 100 indicates extreme discomfort, and > 110 indicates a hazardous to health index for dishwasher and cooks, respectively.

The minimum and maximum discomfort indices (DI) indicate that staff in Durban kitchens are uncomfortable during peak periods of business (Table 7.25 and Table 7.26 page 182). The DI values for dishwashing areas are lower than cooking areas due to the absence of radiant heat. The heavy-duty load kitchens had higher discomfort values than other kitchens being conducted to gather information for the current study.

Table 7.25 Discomfort index near humid zones

Kitchen Zones	N	Minimum	Maximum	Mean	Std. Deviation
Discomfort Index (Stove / Oven)	32	85.22	119.67	103.1350	6.75482
Discomfort Index (Dishwasher)	32	85.83	104.18	98.2101	4.80063

The heavy-duty kitchens use LPG equipment extensively increasing the heat stress of the kitchen workers, whereas, in medium-duty kitchens, only electric equipment is universally operated. This confirms the results reported by Haruyama *et al.* (2010: 143) that workers in LPG kitchens may be exposed to higher heat strains than those in electric kitchens. These outcomes help to compose indoor environmental standards for design of restaurant kitchens with regard to the thermal environment causing heat stress among food production workers using LPG and kitchen appliances. The comparison has predictive potential that contributes towards Objective 2 and Objective 4.

7.6.3.1 Symptoms of flushing

Flushing is commonly known a biological reaction to heat. Flushed skin is often a visual sign of embarrassment, anxiety, or being too hot (Villines 2018: 1). Flushing may be expressed in the equation Y = b0 + b1x1 namely, Heat = 32.907+ (10.152 x symptoms-red face). The coefficient of red-faced chefs is 10.152. Thus for every unit increase in red-faced chefs (BB38.2) as symptoms of heat stress, a 10.152 unit increase in heat near stove area value is predicted, holding all other variables constant. Since p=0.010; less than the significance level of 0.05, there is strong evidence to conclude that the variables are associated. These p-values indicate that the observed difference of more than 1.0% in studies would be observed due to random sampling error, respectively. This equation for dependent variable heat near stoves helps to compose indoor environmental criteria for design of restaurant kitchens in Durban in respect of heat strain in thermal environments.

Table 7.26 Type of kitchen loads observed and Discomfort Index

Type of Kitchen		Discomfort Index (Stove/Oven)	Discomfort Index (Dishwasher)
Light-Duty Equipment	N	2	2
	Mean	**100.5277**	**100.4859**
	Std. Deviation	5.36786	2.66629
	Minimum	96.73	98.60
	Maximum	104.32	102.37
	Range	7.59	3.77
Medium-Duty Equipment	N	5	5
	Mean	**102.6762**	**96.9789**
	Std. Deviation	5.04509	4.99766
	Minimum	93.79	85.83
	Maximum	112.29	104.18
	Range	18.49	18.36
Heavy-Duty Equipment	N	19	19
	Mean	**105.2534**	**97.2802**
	Std. Deviation	14.43691	5.28164
	Minimum	85.22	90.18
	Maximum	119.67	102.37
	Range	34.45	12.20
Extra-Heavy-Duty Equipment-Using Solid Fuels	N	6	6
	Mean	**103.6918**	**102.1251**
	Median	105.1586	102.4424
	Std. Deviation	3.22164	1.46356
	Minimum	97.96	100.39
	Maximum	106.24	104.00
	Range	8.29	3.62

This equation has a prediction quality to achieve Objective 2. Table 7.27 (page 183) indicates that 15.2 % of chefs on duty were observed to be red-faced. As an indicator of heat discomfort and probable heat stress, appropriate management may be necessary (Gao *et al*. 2018: 359). Whilst only 15.2 % of workers in Table 7.27 were red in the face from the heat in cooking areas, the statistic could be misleading as 78 % of African workers were dark in complexion due to ethnicity and hence it was not apparent; some Indian chefs were also darker in complexion. According to Powell (2017: 3), it may seem that Black people do not blush simply because the darker skin colour hides it.

7.6.4 Symptoms of heat stress and heat strain

Heat-related illness is a physiological condition that occurs when the body is unable to dissipate heat adequately, which leads to dysfunctional thermoregulation (Gauer and Meyers 2019: 482). Overexertion in hot weather, exercising or working in hot, poorly ventilated areas can increase the risk of heat stress (Better Health Channel 2020: 1). Welch (2017: 1) posits that employees working in hot kitchens may be at a higher risk of HRI.

Heat strain is the physical response of the body to heat stress environment. If a worker is frequently exposed to hot conditions and internal heat generated through physical work, it can lead to the development of adverse health outcomes. As per Table 7.28 (page 183), 57 % of kitchen workers in the current study reported that they sweat in the work environment. Sweating was obvious among 11.1 % of staff. Heavy sweating, along with headaches, was also reported by 3 % of workers. Sweating amongst 57.6 % of respondents in the present study is shared in similar studies. Logeswari and Mrunalini (2017: 609) report sweating of kitchen workers; Hima Bindu and Reddy (2016: 1321) claim that kitchen workers' heat stress manifests in profuse sweating, exhaustion and irritability due to humidity and hot temperature. Ramsey *et al*. (2014: 12) noted that 44 % workers reported that extreme temperatures made them experience symptoms such as migraines, heat rash, fever, nausea and light-headedness. Roghanchi and Kocsis (2018: 10) claim that hot and humid environments can cause HRI such as thermal stress, heat cramps, heat rash and heatstroke.

Table 7.27 Physiological and psychological symptoms among food service workers

Physiological symptoms	Percent
Tiredness	35.3
Increase in blood pressure	2.9
Headache	14.7
Muscle cramps	2.9
Feeling and being sick	2.9
Heavy sweating	23.5
Intense thirst	35.3
A fast pulse	2.9
Other symptoms	8.7
Not applicable	**41.2**

Psychological symptoms	Percent
Decrease of attention	23.5
Decrease of performance for physical activities	14.7
Slowed and impaired perception	2.9
Decrease of motivation	8.8
Irritability	23.5
Use foul language	5.9
Impairment of thinking	2.9
Lose concentration	8.8
Anger	8.8
Confusion	14.7
Not applicable	**52.9**

Almost 3 % of the chefs in the present study reported high blood pressure and feeling of sickness in Table 7.27 (page 183). The most prevalent symptom of heat stress was tiredness and intense thirst among kitchen workers, which was concurred by 35 % and refuted by 41 % of head chefs. Beheshti *et al.* (2015: 123) find frequently experienced heat-related symptoms of kitchen workers are extreme thirst, mild headaches and tiredness.

Even though more than 50 % of head chefs as indicated in Table 7.27 denied any psychological symptoms shown by kitchen workers due to excessive heat, several kitchen workers (23.5 %), from other kitchens, were observed to suffer from a decrease in attention and or irritability. Confusion (14.7 %) and loss of concentration (8.8 %) were also observed. Impaired perception and impaired thinking were each reported (2.9 %) in one kitchen. Obvious heat strain was observed among 14.7 % of staff. Yip-Hon and Agababova (2018: 1) report workers being uncomfortable, having muscle pain, dizziness, reduced concentration, exhaustion and weakness.

Table 7.28 Heat stress symptoms among kitchen workers

Symptoms of heat strain	Percent
Face-red	15.2 %
Sweating	57.6 %
Uniform is wet-excessive sweating	3.0 %

Heat stress symptoms like flushing and excessive sweating can be reduced by varying heat exchange processes like evaporation, radiation or convection (NIOSH 2015: 71). Engineering controls like forced-air ventilation or capturing heat from the kitchen cooktops or stoves can also reduce heat illness. Further to that, administrative controls can be used to limit a worker's exposure time through rest and work cycles, as well as to reduce the metabolic workload.

7.6.5 Factors affecting heat (°C) near stoves

The equation Y = b0 + b1*x1 + b2*x2 + b3*x3 + b4*x4 + b5*x5 to represent factors that affect awareness of heat while near the stove was used to ascertain the kitchen worker perceptions of heat. Accordingly, heat near stove = 54.547 + (0.982 x S.A. Indian) + (-0.154 x S.A. African) + (-0.829 x number of meals per day) + (-7.334 x other) + (-1.3 x area of the kitchen); “other” refers to QSR serving a seafood-based menu exclusively, or fried chicken and or burger only.

Table 7.29 Factors affecting heat near stoves

Coefficients[a]								
Model		**Unstandardized Coefficients**		**Standardized Coefficients**	**t**	**Sig.**	**Collinearity Statistics**	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	57.557	6.644		8.662	0.000		
	S.A. White Q5.1	0.122	0.131	0.115	0.926	0.368	0.813	1.230
	S.A. Indian Q5.2	0.983	0.275	0.552	3.569	**0.003**	0.522	1.915
	S.A. Coloured Q5.3	0.094	0.948	0.013	0.099	0.922	0.744	1.343
	S.A. African Q5.4	-0.163	0.059	-0.390	-2.752	**0.014**	0.622	1.608
	S.A. Other mixed-race Q5.5	1.964	1.432	0.203	1.372	0.189	0.569	1.759
	European White Q5.6	-0.251	0.317	-0.133	-0.792	0.440	0.446	2.241
	Foreigner Q5.7	0.492	0.762	0.099	0.646	0.528	0.533	1.875
	Area of the kitchen Q6	-1.238	0.523	-0.285	-2.368	**0.031**	0.862	1.160
	Number of meals per day Q7	-0.819	0.379	-0.271	-2.162	**0.046**	0.797	1.255
	Oriental Q12.4	-2.407	1.927	-0.207	-1.249	0.230	0.453	2.206
	Italian Q12.5	-2.139	1.355	-0.311	-1.578	0.134	0.322	3.108
	Other Q12.8	-7.836	1.269	-1.006	-6.176	**0.000**	0.471	2.124

a. Dependent Variable: heat near stove

Heat near the stove experienced by kitchen workers is affected by the race: Indian or African, output in number of meals /day and other factors as well as area of the kitchen.

The coefficient for the area of a kitchen (-1.300) is significantly different from zero (0) because its p-value is 0.027, which is smaller than 0.05. The variables, area of the kitchen and heat experienced near stoves are closely associated. The smaller the area, the more the heat. So, for every unit increase in area, a 1.3 unit decrease in heat experience near stoves area value is predicted, holding all other variables constant, provided this increase in space is not occupied and permits air movement to dissipate heat (Table 7.29). This p-value indicates that the observed difference of more than 2.1 % in studies would be observed due to random sampling error. The coefficients for Indian staff (0.982) and African staff (-0.154) are significantly different from 0 because its p-value is 0.003 and 0.014 respectively, which is smaller than 0.05. Tests for multi-collinearity indicated that a very low level (VIF = 1.915 for SA Indian, 1.608 for SA African, 1.160 area of the kitchen, 1.255 for output in the number of meals per day and 2.124 for other cuisines).

Beta coefficients for three predictors were SA Indian, $\beta = 0.983$, $t = 3.569$, $p < 0.003$; S.A. African $\beta = -0.163$, $t = -2.752$, $p < 0.014$; area of the kitchen, $\beta = -1.238$, $t = -2.368$, $p < 0.031$; output in number of meals per day, $\beta = -0.819$, $t = -2.162$, $p < 0.046$ and other cuisines-seafood, fried chicken $\beta = -7.836$, $t = -6.176$, $p < 0.000$. The best fitting model for predicting heat near the stove is a linear combination of SA Indian, SA African, area of the kitchen, output in the number of meals per day and other cuisines. The volume of food cooked was presented and discussed in section 7.4.3.

7.7 Genotype and phenotype effect on thermal adaptation

Besides personal factors and acclimatisation, genotype and phenotype of an individual play an important role in thermal adaptation (Chevin and Hoffmann 2017: 3). The predominant current-day meaning of *genotype* is the set of genes in the DNA that is responsible for a particular trait. The *phenotype* is the physical expression and behavioural traits of the organism, for example, size and shape, metabolic activities and patterns of movement (Taylor and Lewontin 2017: 1). Examples of genotype are the genes responsible for eye colour, hair colour, height, shape of nose and skin colour. Examples of phenotypes are the actual visible characteristics including eye colour, hair colour and type, height, shape of nose and skin colour. Socio-cultural aspect or race influences heat-stress perception in the workplace according to Messeri *et al*. (2019: 9).

7.7.1 Adaptation to Durban weather

Balakrishnan *et al*. (2010: 3) report that the majority of heat stress complaints were from new workers who are not acclimatised to heat in factories in Chennai. Heat acclimation is an essential heat safety and physical performance enhancement strategy in warm-to-hot conditions (Pryor *et al*. 2018: 37).

Over ninety-eight percent (98.8 %) of the sample (Figure 7.10) liked Durban weather, an indicator that they are acclimatised to warm and sunny weather of the subtropical coastal climate. Only 5.8 % of staff used an air-conditioner at home even though 19.6 % claim to maintain a comfortable lifestyle. It seems a comfortable lifestyle after work is likely to help staff to cool off and come to work well-rested. In its absence, Frimpong (2015: iii) theorises that hot conditions at resting places and poor ventilation at dwellings create a compound effect of heat stress. Almost 91 % of staff travelled by public transport or walked to work whilst 9.3 % drove to work by car.

Hot weather conditions have the potential to exacerbate already high heat conditions and therefore, heat stress inside commercial kitchens. The mean temperature indicated in Table 7.30 can be comfortable for heat adapted residents such as Indians, Africans, people from tropical countries, and semi-tropical countries, which may provide needed space for the raised commercial kitchen temperatures in Durban. Buonocore *et al*. (2020: 1071) report that occupants from tropical climates seem to be more tolerant of the warmest thermal sensations, than subtropical climate occupants in Brazil. Haslam (2013:1) claims that temperature can affect mind and behaviour; independent of sunshine, the more it departs from an ideal around 20 °C the more discomfort one feels in the temperate zone. Humidity tends to make people more tired and irritable.

Table 7.30 Mean values of outdoor temperature and humidity levels during field study

Weather parameters	Mean	Median	N	Std. Deviation	Minimum	Maximum	Range
Temperature (°C)	27.01	27.40	27	2.71	21.60	31.90	10.30
Relative Humidity (%)	63.20	63.25	30	4.44	55.00	79.00	24.00

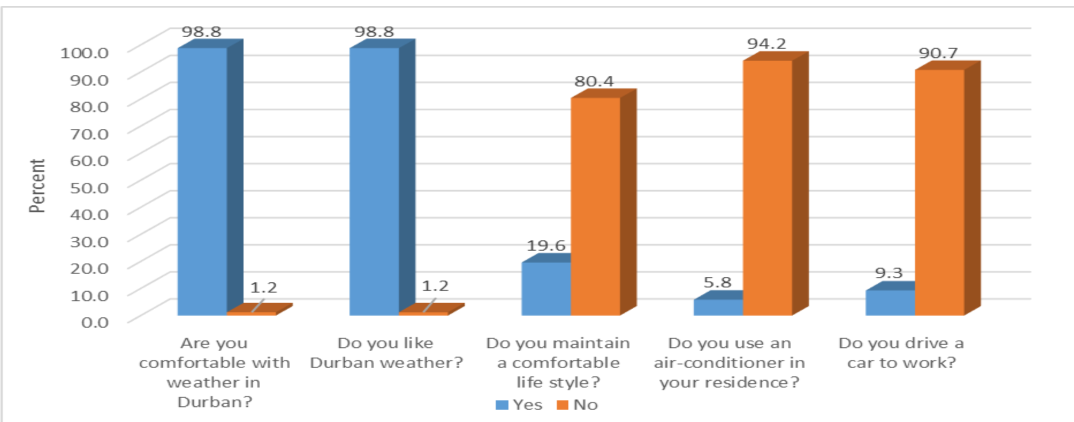


Figure 7.11 Kitchen workers opinion on Durban weather

Li *et al.* (2012:141) had similar weather conditions during the investigation of kitchens in China. During summertime, the comfort conditions in the city centre are associated with greater intensity of Urban Heat Island effect (UHI) effect, which is more pronounced during night time than day time (Poupkou *et al.* 2011: 181). However, the present study recorded outside temperature ranging from 24 °C to 30.80 °C during the fieldwork**.**

The cross-tabulation between kitchen workers comfortable with Durban weather and tenure was found to be statistically significant, the two-sided p-value from Fisher's Exact test was 0.013. The cross-tabulation between kitchen workers liking Durban weather and tenure was found to be statistically significant, the two-sided p-value from Fisher's Exact test was 0.012. The employment tenure was shorter for kitchen workers, with a mean tenure being 4.4 years only.

The cross-tabulation between kitchen workers who have past experience to expect summer months to be hot while maintaining a comfortable lifestyle was found to be statistically significant; the two-sided p-value from Fisher's Exact test was 0.004. Forty-nine percent (49.1 %) of workers expected the day of field study to be hot whilst 37.5 % of workers from their experience, expected summer months to be warm like that of the field study day.

The cross-tabulation between the kitchen worker's comfort in the heat during peak periods and maintaining a comfortable lifestyle was found to be statistically significant. Unison supports the Trades Union Congress call for a specific permissible maximum temperature for indoor work of 30 °C or 27 °C where the work is strenuous. At the moment, there is no officially clear maximum. However, the recommended maximum would be intended to be the absolute maximum, so regular indoor work at or just below 30 °C would not be acceptable, and that managers should endeavor to reduce temperatures if they went above 24 °C or workers felt uncomfortable. According to Unison (2014: 2) the WHO recommends 24 °C as the maximum temperature for working in comfort.

As $p=0.05$ is significant between kitchen workers maintaining a comfortable lifestyle and using make-up at work, strong evidence to conclude that the variables are associated. There is a dearth of literature on the concept of comfortable lifestyle among food service staff. This study is an exploratory study and hence, relevant literature is not available. The cross-tabulation between kitchen worker's perception of feeling comfortable working in the kitchen with makeup or foundation and BMI was found to be statistically significant; the two-sided p-value from Fisher's exact test is 0.050.

7.7.2 Kitchen worker's uniform

Eighty-one percent (81 %) of the workers (Appendix 5) were comfortable in their uniforms. However, at the time of the survey, not all kitchen staff, wore a chef's jacket. Food service establishments appear to have favoured comfort over safety and permitted staff uniforms to be more casual (Industry Insights 2017: 2). Hence, almost 39 % of the kitchen workers in the present study were wearing a regulation T-shirt; even a house-coat for female chefs (Appendix 4).

Food Republic (2015: 1) reports that some chefs consider the staple kitchen garment as not only unfashionable but also unnecessary and uncomfortable; they would prefer to cook in an old T-shirt instead. The observation concurs with Logeswari and Mrunalini (2017: 609) who recommend light clothing worn to prevent heat stress when working at the open kilns. Although there are several heat-related work remarks about uniforms in workplaces, studies relevant to clothing discomfort is limited and does not mention the listed uniforms worn in the sampled kitchens.

Half (50 %) of the kitchen managers (Table 8.14 page 231) claimed that staff complained with regard to humidity such as sweat not drying, wet uniforms and stickiness. In very hot periods, the human organism makes use of perspiration to maintain its temperature within proper physiological limits.

Singh *et al*. (2016: 4) reported that male kitchen workers wear aprons and head-coverings in the kitchen over casual clothes. Females in India are mostly (99 %) dressed in loose-fitting Indian attire with much better scope for thermal adaptation (Indraganti *et al.* 2015: 288). This is totally in contrast with Lundgren-Kownacki (2018: 57), who claims that female workers are more prone to heat stress due to the use of clothing that inhibits heat dissipation. Females were identified as more vulnerable due to the practice of wearing a protective shirt over traditional clothing at work, which increases the thermal discomfort.

Schiavon *et al*. (2016: 5) reported that smart casual office attire for tropical climates. Cao *et al.* (2012: 396) argues that the amount of clothes occupants in public buildings of China wore varied greatly during the different seasons. The researcher observed that 96.5 % of the food service workers in the sampled kitchens wore long pants, except for 3.5 %. Golf shirts and formal shirts in kitchens were observed among 12 % and 3.5 % of kitchen workers respectively.

The cross-tabulation between kitchen workers feeling comfortable working in chef's uniforms and the number of meals prepared in a single shift was found to be statistically significant; the two-sided p-value from Fisher's exact test was 0.045. Only one chef had a wet uniform due to excessive sweating.

The correlation $p=0.000$ is significant between the kitchen worker's uniform and the number of meals cooked per shift. Parameswarappa and Narayana (2014: 863) reported that steelworkers' wore a heavy PPE ensemble. According to the OSHA fact sheet (2003: 1), use of bulky protective clothing and equipment may contribute to heat illness. As explained earlier in this section, a chef's uniform can prevent heat dissipation. The greater the meal output, the greater the discomfort from workers' uniforms.

7.7.3 Hairstyles and head covering

In experimentation of the influence of head hair on heat removal, Shin *et al*. (2015: 540) found that the optimal temperature for head cooling under heat stress was 10 °C to relieve physiological heat strain; subjects, however, reported to prefer 15 °C.

Appendix 24 indicates cross-tabulation between A30= less hair or clean-shaven head will be comfortable to work in the kitchen and B1= the heat at the workplace and divulges a value of p=0.019. There is strong evidence to conclude that the variables are associated.

Shin *et al*. (2015: 540) contend that heat removal from the normal hair condition, namely, 100 mm to 130 mm length and cropped hair, 5 mm length condition was not significantly different. However, Jacoby (2018:1) claims that long hair has a similar effect to hats which induces sweat, and cool down the body. However, short hair will be cooler for the head. It seems that commercial kitchens in Durban do not specify the length of hair among kitchen workers as a hairnet or a cap or a chef's hat covers the hair based on uniform regulation for staff. If the restaurant were a chain or franchise, then the hairnet rule would apply to everyone without any exceptions (Jacoby 2018: 1).

The cross-tabulation between kitchen worker's perception of feeling comfortable with excess hair to work in the kitchen and BMI was found to be statistically significant; the two-sided p-value from Fisher's exact test is 0.012. Almost 48 % of African workers had dreadlocks, hair extensions and hair weave. Almost 70 % of them were female workers and 29 % were male workers. Even though artificial hair is not preferred in kitchens, once covered, it is acceptable. The female workers voiced their opinion that hairstyles were part of grooming and hence they indulged in hair extensions and weaves (Appendix 6). About twenty-eight percent (28.2 %) had elaborate synthetic hair on their heads. There is a scarcity of evidence in literature on the relevance of comfort with excess hair to work in the kitchen.

Almost 77 % of kitchen workers of African descent agreed that they do not feel comfortable with excess hair in the kitchen. Significantly more respondents indicated that they were uncomfortable with excess hair and that being shaven would be more comfortable working in the kitchen with 64.2 % ($p < 0.001$). Appendix 7 indicates the common hairstyles among sampled kitchen workers.

According to Esther (2008: 1), local authorities in UK require chefs to wear a hairnet even if bald. Wearing wigs can be uncomfortable and can be cumbersome with heat and humidity. A synthetic wig may melt near a hot stove/oven (Stephen 2018: 1). Dreadlocks can be hot and heavy, especially when the temperature is 90 °F (32.2 °C). This is an uncharted field in thermal comfort in the kitchen.

7.7.4 Body Shape

An individual's overall body shape is a superior indicator of climatic adaptation than a single facial feature. Individuals who adapted to warm climates tend to be slender, and persons adapted to cold climates tend to be thickset (Aryan Anthroplogy 2015: 2). The widely used classification of body types is ectomorphic, mesomorphic and endomorphic (Abubaker 2010: 3). Consistent with Bergmann's Rule and Allen's Rule, warm-adapted individuals tend to be lean ectomorphs and cold-adapted individuals tend to be bulkier non-ectomorphs. Appendix 8 indicates that body type among kitchen workers is based on the researcher's perception. Observations that are more accurate would have been yielded from the use of a somatotype calculator.

South African men working in kitchens tend to be stocky with almost 65 % having normal weight whereas only 31 % of women had normal weight for height. More than half the women workers were obese (55 %) and endomorphic, however, only 16 % of men were obese. Although none of the men was morbidly obese, 7% of women were. Overweight and obese kitchen workers may experience higher discomfort levels as Habibi *et al*. (2016: 1) observe a higher risk of heat strain in overweight subjects. Nearly 20% of men were ectomorphic and lean, seven (0.64%) women were lean and slender. Ganguly (2013: 49) declares that mesomorphs maintain improved physical fitness and hence tolerate heat better with lower heat stress. There are no studies to indicate if the skin tends to 'burn easily' from indoor heat.

7.7.5 Skin colour

Very fair skin tone, as well as black skin tone, or extremely dark skin tone was observed in 2.9 % of kitchen workers. Variation exists in the skin tones among African workers from medium fair to black. Medium brown was the most commonly observed skin tone among Africans with more than 54 % workers as indicated in Appendix 9. Since 90 % of the workers were African who tend to have a darker skin tone, the scale was converted from 10-point into a 7-point scale by the researcher for easy data recording as fairer tones were rarer in the survey. The Fitzpatrick scale included skin types I–IV (moving from light, always burns to dark, never burns), but later modified to include darker skin types V and VI (Tang *et al*. 2015: 12). Pigmentation is correlated with the amount of UV radiation a region receives which correlates with warm humid areas. It has been established that dark skin tone protects from warm temperature and sunlight, but protection from indoor occupational heat stress is unknown. Okada (2020: 1) claims that skin colour does affect body temperature as melanocyte, a skin cell that stimulates melanin production has a major impact on the skin's heat sensitivity.

The cross-tabulation between kitchen worker's skin tone maintaining a comfortable lifestyle was found to be statistically significant; the two-sided p-value from Fisher's Exact test is 0.001. It seems that staff maintaining comfortable lifestyle have lower heat stress. Not all workers can cool their bodies adequately at night and such individuals are at greater risk for HRI (Frimpong 2015: iii). It has not been established in the literature that the skin tones of the kitchen workers have any benefit in dealing with indoor heat, specifically kitchen heat. Even the advantage of ethnicity and heat adaptation is contentious.

7.7.6 Type of nose

An investigation by Zaidi *et al*. (2018: 1) claims that the width of the nostrils is strongly correlated with thermal comfort indicators temperature and humidity. A funnel nose silhouette was the most commonly observed nose among African kitchen workers (71 %). Although other nose types like large, button and upturned were also noticed among Africans, the frequency was low as indicated in Appendix 10. Big noses were seen across various ethnicities (5.2 %) except Caucasian. Snub noses were more common among women across all races. Sharp straight noses were seen among Caucasians and Indians.

The available literature appears to dwell in investigations of funnel nose and aquiline nose in terms of the nasal index. Possible effects that these shapes have for alleviation of kitchen worker heat strain is not supported by prior studies in the literature.

The marked diversity of nasal shapes among living human populations has long been considered a consequence of adaptation to a wide range of climatic conditions for optimising respiratory heat and humidity exchange in the nasal mucosa (Yokley 2009: 11). Unlike in excessively-dry warm and cold environments, aquiline, or 'beak-like' noses are adaptations to cold as they provide a larger region for air to be warmed and humidified before being transferred to the lungs **(**Aryan Anthropology 2015: 2). Funnel nose or snub nose among Africans helps to breathe in warm moist air quickly. This characteristic seems to alleviate heat stress in hot kitchens. It further states that traits such as skin pigmentation and nose width have evolved faster than most other traits which are likely due to natural selection because of exposure to the environment.

A relationship was established between opinions of kitchen workers on heat in kitchens and type of nose; p= 0.046; less than the significance level of 0.05 and hence strong evidence to conclude that the variables are related.

7.8 Conclusion

This chapter explored the implication of physiological factors, genotype and behavioural factors on heat adaptation. Human heat adaptations vary widely. Heat in kitchens has been shown to be affected by kitchen activities, type of equipment, fuels used and cuisine. Physical and psychological heat stress symptoms was observed in some kitchens. It is important to have models for heat stress prediction to diminish thermal risk and avert heat-induced disorders in different exposure settings. The analysis and appraisal of answers require trans-disciplinary and holistic approaches, including technical solutions and a mix of locally appropriate technologies integrated with a human rights and environmental justice frame. The next chapter will discuss how findings on the kitchen ventilation rates affect thermal comfort and humidity levels.

CHAPTER EIGHT

DATA PRESENTATION, ANALYSIS AND DISCUSSION: VENTILATION AND HUMIDITY

8.1 Introduction

The previous chapter deliberated on the primary data results of parameter heat in this exploratory study. This chapter will discuss the findings on ventilation and humidity in kitchens. The discussion begins with airflow in kitchens, natural ventilation (NV), kitchen spaces, air composition and CO_2 levels, followed by humidity. The findings will be presented according to the emerging themes.

8.2 Architectural features suitable for kitchen ventilation

Architectural design can be influenced by several factors including air circulation and movement, NV of buildings can inspire the achievement of breathing architecture (Stavridou 2015: 131). A space to accommodate human life should essentially include air that contribute to the promotion of the well-being of occupants (Stavridou 2015: 129).

8.2.1 Sources of airflow in kitchens

Airflow inside a building is determined by external drafts as well as on the architectural parameters. Architectural means for attaining this aim comprise of conventional design features such as location and alignment of building, roof shape, balcony configuration, type and location of windows, partition and furniture arrangement (Al-Tamimi and Fadzil 2009: 370).

Sources of ventilation in the sampled kitchens were inclusive of open doors, open windows, hatches, fans, air coolers, air-conditioners, whirlybirds, chimneys, HVAC extraction systems and NV from the sea breeze helped dilute ventilation in kitchens. In some kitchens, these ventilation modes per Table 8.1 (page 195) were found to be inadequate to cope with the heat and fumes.

Greenplan (2015: 1) posits that earlier building designs relied on NV to ensure adequate fresh air and acceptable thermal comfort as seen in almost 80% of the kitchens. The benefits associated with NV, include improved IAQ, maintenance and energy usage, with a trend to re-introducing this into building designs. Sustainable Energy Africa (2017: 65) reports that the stack effect, interior open doors open, and a combination of open windows and exterior doors creates a draft. The air moves through the kitchen to push stagnant, polluted air out (Cameron 2019: 1).

Table 8.1 Ventilation facilities in sampled kitchens excluding extractors

Fenestrations				Built Spaces				Mechanical Devices				
Kitchen no.	**Back door open**	**Front door open**	**Window open**	**Large corridor**	**High ceiling**	**Spacious areas**	**Open-plan**	**Air-conditioner**	**Air vents /diffuser**	**Whirly**	**Fans**	**Air Curtain**
1	✓	✓					✓				✓	✓
2	✓	✓			✓	✓	✓		✓	✓		
3					✓	✓						
4		✓					✓		✓	✓		
5		✓				✓	✓	✓				✓
6				✓		✓		✓				
7	✓			✓	✓	✓						
8	✓											
9	✓		✓								✓	
10	✓	✓									✓	
11	✓	✓									✓	
12	✓		✓				✓				✓	
13	✓				✓	✓						✓
14		✓					✓					
15		✓					✓			✓	✓	
16		✓					✓					
17		✓		✓			✓					
18								✓				
19								✓				✓
20								✓			✓	
21		✓					✓		✓	✓		
22							✓		✓			✓
23										✓		
24		✓					✓		✓			
25		✓					✓		✓			
26	✓							✓	✓			
31	✓											
27		✓					✓			✓		
28	✓	✓									✓	
29	✓											
30	✓	✓										
32		✓	✓						✓		✓	
33	✓	✓	✓									
Total	13	16	4	3	4	7	13	6	8	6	8	4
%	**39.4**	**48.5**	**12**	**9.0**	**12.1**	**21.2**	**39.4**	**18**	**24**	**18**	**24**	**12**

8.2.2 Kitchen fenestrations, open-plans and mechanical devices

Afework *et al*. (2018: 1) describe fenestration as openings in the building envelope, including the installation of windows, doors and skylights. Yi *et al*. (2016: 181) state that NV is least efficient and the concentrations of impurities in the indoor space would vary depending on the outdoor wind directions.

The researcher surmises that coastal Durban has reasonable airflow that can be harnessed in kitchens, despite the wind-power potential in the general Durban region being classified as moderate (Bellingham *et al*. 2009: 10). Prior studies linking natural sea breeze into restaurant kitchens appear unavailable.

According to Mehta (2019: 1), fenestrations create porosity in buildings to permit ventilation. The researcher proposes that fenestrations constitute a passive cooling strategy: the intentional movement of outdoor air through an enclosure under the influence of wind and thermal pressures through controllable openings. The researcher established that air infiltration in kitchens was assisted by fenestrations in the building envelope (Table 8.1 page 195).

None of the kitchens had tightly sealed doors and windows. The air infiltration from open doors, windows, whirlybirds and chimneys helped with NV. The large difference in the thermal environment between summer and winter in casual kitchen types was probably due to more frequent use of NV for cooling (Simone *et al*. 2013: 1002). Not all kitchens had the same equipment or design layout, and this could have influenced NV.

Commonly observed across the open-plan design of 13 kitchens with features in Table 8.1 were the airflow from the front doors and the cool airflow from dining areas. The shutters on either side of a room provide for cross ventilation within a building. This passive cooling technique was observed to be beneficial during the summer months. Open-plan kitchens benefit with the creation of cross ventilation from high ceilings, large corridors, open doors and windows.

8.2.3 High ceilings and large corridors help with air movement

Albeit in the context of residential kitchens, Mofrad (2014: 286) proves that 2.7 m and 2.8 m is the most desirable ceiling height. In the present study, ceilings higher than 4 m in three kitchens helped to keep kitchens cooler. The sampled kitchens had a mean of 3.03 m with the lowest ceiling height of 2.41 m; a median of 2.96 m; and a maximum of 4.17 m. More than 30 % of the kitchens had a ceiling height less than 3.0 m. Ceiling heights for commercial kitchens are inappropriately not mentioned in prior ventilation studies. Stoakes *et al*. (2011: 373) posits that the main reason for high ceilings is to facilitate airflow in summer. Lotfabadi and Hançer (2019: 2) add that increasing ceiling height leads to an improved sense of thermal comfort in summer, particularly in hot and humid climates; the air volume is greater and creates more vertical temperature differences and air movement.

Following on Aflaki's *et al*. (2015: 151) contention that corridors are significant in channelling and delivering airflow into parts of a building, the present study found this occurred in two kitchens that had large corridors that observably enhanced NV with higher airflow rates. An architectural element such as corridors creates cross ventilation and connects the outdoor environment and isolated indoor space. In this regard per Table 8.1 (page 195), kitchen six is ideally located in an open space on a hillock closer to the ocean. The kitchen is located in the basement on one side and slopes up to ground level. The sea breeze is channelled through a long curved corridor to reach the spacious kitchen where it is removed by an extractor even though the velocity of the gushing air is reduced. Spacious kitchens (21.2 %), high ceilings (12.1 %) and large corridors (9.0 %) were observed in the sampled kitchens though only one kitchen had all the three ventilation facilities. However, the oxygen levels in these kitchens were 22 % compared to other kitchens that indicated 21 %. As per Mukhtar (2018: 42) OSHA (1997) recommends a concentration level between 19.5 % to 23.5 % at 760 mm Hg.

8.2.3.1 Natural ventilation from windows and doors

Open windows and doors providing NV are often the only means of providing cooling when mechanical air-conditioning is not available. The NV range can improve comfort between 9 % and 41 % in tropical climates, and between 8 % and 56 % in temperate climates (Haase and Amato 2009: 389). Buildings with operable windows and NV have 3.2 % reduced nonattendance compared to closed buildings with air-conditioning (Window Master 2018: 12).

According to Pennycook (2009: 8), robust window handles, stays, controls and free window areas can determine the ventilation effectiveness. Sherman (2004: 4) concurs that windows could be used for ventilation provided the openings do not present a hazard. Windows in the kitchen should preferably be less than 10 % of the total floor area, looking out to the sky or open spaces (Nisbets 2019: 1). The researcher, however, did not observe any electronically controlled windows in the present sample. It seems the windows were opened and closed manually when necessary.

Closed doors obstruct kitchen airflow (Bonderud 2015: 1). In response, kitchen 11 accordingly installed a security gate that permitted leaving the back door ajar until closing time to permit airflow into the kitchen, hence improving cross ventilation. Back doors were present in 23 kitchens and five kept it closed, using it only for receipt of deliveries. Air velocities varied from 0.10 m/s to 2.5 m/s at the back doors of the sampled kitchens. Nearly 55 % of the kitchens kept the doors open most times, so allowing airflow that helps reduce ambient temperature and stuffiness. Kitchen 11 had a back door secured with a cage and a mesh wire left it ajar for airflow during operation.

Whist seemingly obvious that NV in the kitchen can be enhanced by aligning the building to use the prevailing wind breezes for cooling, the limits on kitchen design often constrains such benefit. The NV in 30 % of the sampled kitchens in the present study was restricted by the absence of back doors which could be due to location factors and availability of rental space. This resonates with the study of food stalls by See and Balasubramanian (2006: 369).

Whelan (2015: 17) recommends the strategic placement of windows (openings without glass) and doors informed by prevailing wind patterns in developing countries to improve the ventilation in the cooking space. The researcher, however, contends that total dependence on NV to exhaust heat flux and emissions in a commercial kitchen is arbitrary.

8.2.3.2 Whirlybirds and fans assist in natural ventilation

Eighteen percent (18 %) of the sampled kitchens (Table 8.1) installed turbine ventilators that improve airflow in the kitchen according to Shieh *et al*. (2010: 2341). Solarwhiz (2018: 1) points out that whirlybirds as well as stack ventilation systems effectively extract heat. Hughes and Ghani (2008: 1651) established that the wind vent could provide the recommended fresh air rates at relatively low external wind velocities in buildings. Hence, even in urbanised or well-shaded applications, the device is a viable complement to mechanical ventilation.

Fans were present in 24 % of sampled kitchens that circulated air to speed up the evaporation of sweat, hence giving a cool feeling to workers. Whelan (2015: 68) reports on an experiment that greatest improvement in air quality can be achieved through a combination of a cross-kitchen airflow using industrial pedestal fans and open windows. Using ceiling fans to mix the air creates consistent temperatures throughout the food preparation area, eliminating troublesome hot and cold spots (Kegley 2016: 1).

For a coastal kitchen, Honeywell's (2019: 2) recommendation to use tower fans in cooler, humid areas may be useful in the present context. According to Vu (2019: 2), the average speed of a fan is 2.9 m/s depending on the switch position. High velocity heavy-duty industrial fans in 24 % kitchens either pedestal or wall, were installed to compensate for inadequate airflow. However, Perkins (2018: 1) recommends spot cooling with small fans to reduce strain on kitchen employees as well as refrigeration systems. Detailed measures of fan speeds were beyond the scope of this study and further discussion is hampered by the paucity of literature on these viewpoints.

8.2.3.3 Air curtains, air vents and air-conditioners

Air curtains were installed in four kitchens at the entrance. Air curtains promote a healthy and hygienic environment in a restaurant by re-circulating facility air in a smooth flow across an open doorway, making it harder for outside air to penetrate the air curtain (Schwank 2019: 1). Air curtains prevent the loss of cooled air to preserve the interior temperature. Hueda (2020: i) suggests that that an inclined air curtain may be installed if the kitchen hood is not good enough as they are greatly effective against problems of hoods.

The correct size, type and number of ventilation units required for any area is determined by the kitchen size, its use and location (Vent-Axia 2019: 1). Ventilation rates vary between food service facilities due to site- and equipment-specific factors such as operating hours and extraction system features (Better Buildings 2015: 2).

Air vents (24 %) and air-conditioners (18 %) help to mitigate staff discomfort from heat and humidity with cool air. Vents are openings to achieve the ventilation flow based on climate and geometry of the building design. The sizing of openings is a part of the ventilation strategy (Atkinson *et al*. 2009: 41). At least two combinations to improve ventilation were noted in 18 kitchens (Table 8.1). Properly inducing NV can significantly improve IAQ and decrease reliance on air-conditioning, thus cutting energy consumption (Shieh *et al*. 2010: 2341). To maintain sufficient indoor conditions year-round, the air-conditioning system in kitchens is always needed (Kosonen 2014: 2). Using air-conditioning and fans is another way to ensure the comfort of kitchen workers (Die-Pat 2016c: 2).

8.2.4 Kitchen spaces

The space required for all functional areas of kitchens such as receiving, storage, preparation, cooking and dishwashing depend upon many factors to produce menu items (Laine *et al.* 2014:1). Sethi and Malhan (2015: 65) posit that space should be planned and organised to be comfortable for kitchen workers. Conversely, Maruthi *et al*. (2013: 4) report that cooks work at stoves in congested kitchens in the food parlours of India. Thirty percent (30 %) of the kitchen staff interviewed by the researcher in the present study considers the kitchen workspace to be inadequate; the rate of airflow is therefore questionable. Airflow in a kitchen seems to be affected by area and the volume of kitchens, volume of food cooked, cuisine and density of workers in the kitchen and air infiltration. Atkinson *et al*. (2009:

43) suggests that furniture layout and internal partitioning must permit the intended flow path and open access to airflow. Kitchen 29 and 31 had half walls/semi partitions between different sections of the kitchen to permit air distribution. Indoor Air Quality in kitchens 3, 6, 7, and 14 in section 8.2.1.i was better compared to other kitchens as the temperatures did not exceed 30 °C due to the presence of good natural ventilation from the ocean breeze, PPS, air-conditioners and air curtains. These kitchens also had large unoccupied spaces, so permitting airflow in different kitchen areas.

8.2.4.1 Size of Kitchens

While most of the kitchens areas were less than 100 m², a few had areas greater than 300 m². The calculated volume of sampled kitchens ranged from 43.58 m³ to 426.05 m³ (Table 8.2). Astolfi and Filippi (2004: 1202) observed variations in volume from 99 m³ to 191 m³ in restaurant kitchens. Simone *et al.* (2013: 1002) contend that because the determinants of restaurant type, for example, casual restaurants, institutional restaurants or quick-service restaurants (QSR) require different kitchen activities such as preparation, cooking and dishwashing, with varied building and types of HVAC systems, insulation, windows, air-conditioning, NV is necessary. The standard minimum formula for a full-service dining establishment is 5 ft² (0.46 m^2) of kitchen space per restaurant seat: a 40-seat restaurant requires a 200 ft² (18.58 m^2) kitchen. Fast-food quick-service operations and restaurants that use pre-packaged convenience foods and need lower storage and preparation areas with lesser space (Perkins 2018:1).

The current study observed that the area of the kitchens varied between 17 m² to 334 m² and the mean value was 68.41 m²; the number of the meals consumed daily was between 85 and 1 200.

Table 8.2 Kitchen sizes and workspace ratio

Kitchen dimensions	Mean	Median	N	Std. Deviation	Minimum	Maximum	Range
Seating Capacity	93.48	75.00	31	74.46	12.00	320.00	308.00
Number of Employees	17.88	15.00	33	9.25	9.00	45.00	36.00
Width (m)	5.63	5.32	33	1.39	3.25	8.86	5.61
Length (m)	9.08	7.82	33	5.32	4.30	28.00	23.70
Height (m)	3.03	2.96	33	0.51	2.41	4.17	1.76
Area (m²)	68.41	44.87	33	54.07	17.10	334.08	316.98
Volume (m³)	204	132	33	170.04	40.8	1053	1012.00
No. of staff on duty	7.87	7.00	33	3.14	4.00	17.00	13.00
Workspace ratio (m²/employee)	8.05	6.23	33	5.00	2.67	21.23	18.56

City of Durban (2020) Food By-Laws (Provincial Notice No. 627 of 1950) requires a food preparation area, exclusive of the scullery with a floor area of 18.5 m²; a scullery with a floor area of 4.6 m²; a storeroom with a floor area of 16.75 m² and a shop with a floor area of 28.0 m². However, it was observed that a certain franchise kitchen with three different themes, cuisines and menus sold had smaller floor areas (~ 17 m²) operating with a large common preparation area serving all 3 kitchens. Almost 91 % of the kitchens had preparation areas of 18.5 m² or more. In Tehran, Ghasemkhani and Naseri (2008: 59) confirm that the average area of kitchens varied from 18 m² to 134 m² in restaurants. On the other hand, Malekshahi (2013: 44-65) later reports that restaurant kitchen sizes in Cyprus ranged from 117 m² to 212 m².

The area of the kitchen seems to influence the airflow in the kitchen. Figure 8.1 indicates area of the kitchens. Significantly, more respondents (86.7 %) indicated that the kitchen area was less than 100 m^2 ($p < 0.001$). Kitchens 6, 7 and 14 had larger areas leaving additional unoccupied space for air circulation with kitchen areas ranging from 173 m² to 332 m².

Various measures for kitchen space have been advanced. For example, 0.46 m² space for every seat in the front of the house (Die-Pat 2016a: 1); 30 % of the total square footage of the restaurant and full-service restaurants; a 60-40 ratio is a baseline for allocating space, 40 % allocated to the kitchen, storage and preparation areas (Perkins 2018: 2).

Almost 88 % of the sampled kitchens fell in the range of 30 % to 40 % space allocated to the kitchen when compared with dining areas. About four kitchens were larger than most kitchens and occupied 60 % of space when compared to dining spaces. This can be attributed to a kitchen servicing other satellite kitchens, another kitchen offered food 24 hours including room service and had a patisserie attached to it, and another two kitchens offered fine dining services. The minimum size of a kitchen with accommodation up to 50 seats must be, at least, 20 m² including the washing area. For greater receptivity, 0.5 m²/seat are calculated (Biblus 2020: 3). A kitchen size metric is the number of guests served at any given time. The rule of thumb is to allocate at least 5 ft² (0.445 m²) for every seat in the dining area (Manu 2019: 1).

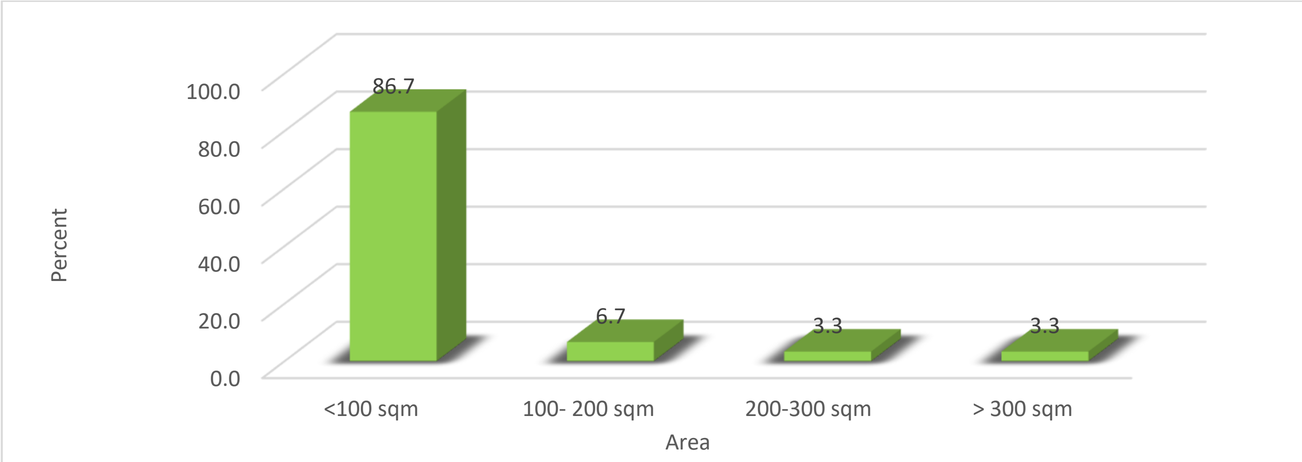


Figure 8.1 Kitchen areas in the current study

Ghiselli *et al*. (2006: 90) earlier reports that twice as much space (1.99: 1) on average had been assigned to the dining area as to the kitchen area, but there were variations by type of food service. The most common standard ratio offered for a dining room to kitchen space is highly variable and depends largely on the type of restaurant. The Evans Group consulting firm recommends a 3:1 ratio, with the smaller share for kitchen use. Fine dining food requires two to three times the kitchen space necessary for banquet service, fast-food establishments can have smaller kitchens and larger dining rooms. These kitchens can occupy as little as 25 % of the total floor space, for a 4:1 dining area to kitchen ratio (Decker 2019: 1). To maintain effective movement through spaces, the area/person according to the use of the equipment as given by Aluline (2019: 9) has established by the Building Act (1984) of Workplace Health, Safety and Welfare Regulations 1992. It is recommended that in a kitchen, each staff member needs 10m².

8.2.4.2 Worker density in kitchens

For the purpose of this study, density is the number of people per unit/area (National Geographic 2019: 1). Employment density refers to the average floor space (m²) per full-time equivalent (FTE) member of staff. It is used to measure the intensity of the building use and an indicator of how much space each individual occupies within the workroom. According to the U.K. Homes and Communities Agency, the Employment Density Guide, (2015: 29) has FTE of 15 to 20 for restaurants and café. The number of staff members on duty (Table 8.2 page 200) varied from four to seventeen, and within the value of this guide; however, South Africa is yet to formulate such a guideline.

The number of personnel in measured kitchens varied from 1 to 20 persons per Heinonen (1997: 395). The number of staff members in the sample kitchens ranged from four to thirty-one depending on the shift and day of the week. Rasmussan (2015: 2) reported that the City of Sydney had 22 m² per employee in the food and drink industry whereas; it was 18 m² per employee in restaurants and cafes in the U.K. A survey of existing kitchens in UK by Pawas.com (2018: 3) revealed that the space varies from as little as 2 ft² (0.185 m²) per meal served to as much as 7 ft² (0.650 m²) or more. This figure includes the area for ancillary rooms as well as for the main kitchen. The workspace ratio measures the amount of floor space per worker; 13 m² per employee in restaurants in UK whereas, the national average was 18 m² per employee in the USA (Smith 2018: 1). The workspace ratio varied from 2.67 to 21.23 in the sample kitchens. Heavy-duty and light-duty kitchens had ratios of 7.88 and 9.4 respectively (Figure 8.3).

Simmons (2019: 1) claims that workspaces of 7.4 to 13.9 m²/employee is considered as high density. The researcher feels that a workspace ratio of 18 m²/staff may be suitable in warmer countries, unlike the temperate UK. Under Facilities Regulations of the Occupational Health and Safety Act 85 of 1993 SA, 2.25 m² of unimpeded space of open floor area to be available for every employee working in an indoor workplace. However, no mention of the hospitality and catering industry is made. As per Energy Code Ace (2013: 2), California Building Code commercial kitchen occupant densities recommended is 200 ft²/occupant (18.58 m² /occupant).

Mibey and Williams (2002: 2) confirmed that with cook-chill systems, lower staff ratios were observed than those with cook-fresh systems (8.3 vs 6.4 customer or full-time equivalent staff; $p<0.05$), but there was no significant difference in the ratio of meals served per FTE. Nearly 97 % of the kitchens in the current study followed cook-fresh system/conventional food production system. On-site food preparation dominates production systems used in restaurant settings. The number of workers in kitchens can affect ventilation (Figure 8.2). The density of workers is important to determine environmental comfort because the greater the number of workers in the kitchen, the greater the space required in to maintain adequate ventilation rates. A very large number of stations intended for meal preparation are positioned adjacent to one another in a small area, and a large number of employees work at these stations (Marć *et al*. 2018: 2071).

Seventy-four percent (74 %) of the kitchens employed at least 10 staff. Only 2.9 % of kitchens had more than 25 employees in a food service operation. Nearly 15 % of kitchens had more than 15 employees in the food business. The distribution of staff according to kitchen load is indicated in Figure 8.3. The most common heavy-duty equipment kitchens (61%) had a workspace ratio of 7.88.

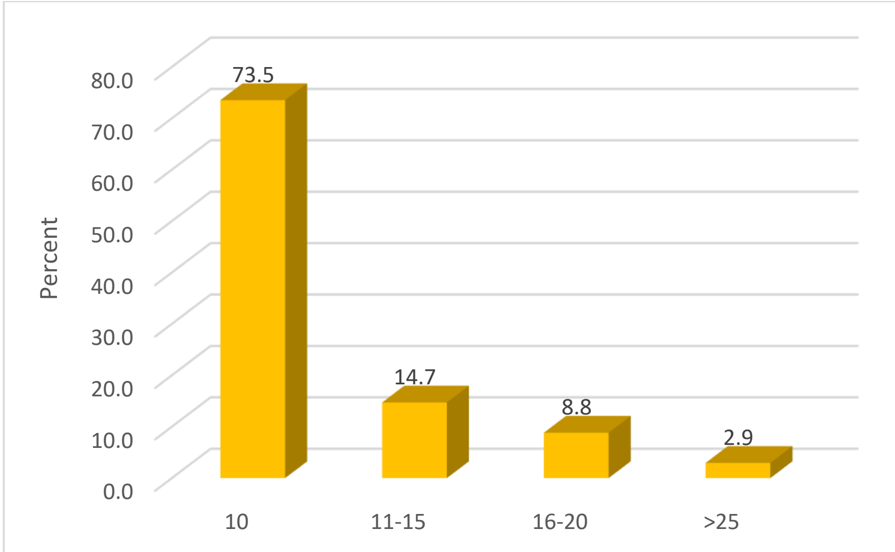


Figure 8.2 Worker density in the kitchen

Medium-duty kitchens were found to have the highest workspace ratio of 10.16, whereas extra-heavy-duty kitchens had the lowest ratio of 5.60. Importantly, Attia (2012: 35) states that it is important to design spaces to create environments of personal well-being.

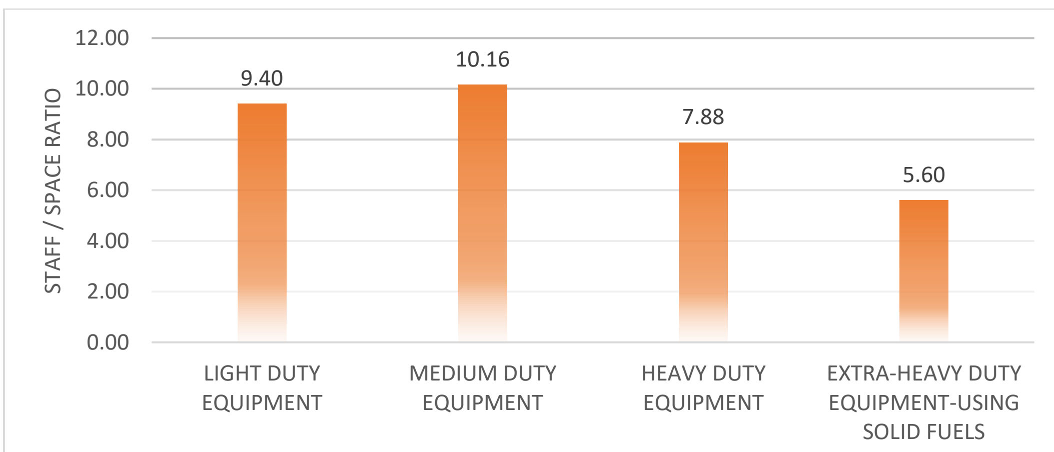


Figure 8.3 Workspace ratio

8.3 Airflow in commercial kitchens

Indoor air distribution determines IAQ and human comfort (Li *et al.* 2019: 505). A minimum airflow of 0.5 m/s in every kitchen zone can be ideal. However, the present study indicates that there was no airflow in 12 % of kitchen zones of sampled kitchens (Table 8.3). Although 60 % of the kitchens had an adequate airflow rate of 0.5 m/s, it was uneven in some areas. People feel comfortable at an airspeed of about 0.25 m/s (Cengel and Boles 2007: 729) whereas Boduch and Fincher (2009: 3) claim that airflow managed slower than 0.5 m/s feels pleasant. However, Faizal *et al.* (2011: 8) recommend air velocities less than 0.9 m/s. The ASHRAE Standard 55 suggests airspeeds below 0.20 m/s in the predicted mean vote (PMV) model. It is acceptable to use airspeeds greater than this to increase the upper temperature limits of the comfort zone in certain circumstances. Kumar *et al*. (2020: 17) find the acceptable range of indoor airspeed to be 0.32-2.00 m/s and 0.00-0.50 m/s during autumn and winter season, respectively with male students accepting slightly higher airspeed than females. Yan *et al*. (2020: 1) report that airspeeds of more than 1.0 m/s have a cooling effect in air temperature above 33.5 °C in hot-humid regions. Zhai *et al.* (2015: 178) recommend airspeed of 1.2 m/s at 30 °C with a relative humidity of 80 %, which exceeded the upper limit, set in the ASHRAE Standard 55 (0.8 m/s). Kumar *et al*. (2020: 173) report that due to an increase in airflow, some of the occupant conditions are found in the acceptable range even at a higher operative temperature of 30.5 °C.

The mean airflow measured between 0.08 m/s to 0.47 m/s in dishwashing areas and corridors, respectively. Moreover, the range from minimum to maximum across all kitchen work areas varied from 0.00 to 2.5 m/s (Table 8.3). These airflow rates are dissimilar to Simones' *et al*. (2013: 1007) findings across 105 kitchens in the USA. These airflow rates are much lower than her study. Higher airflow values in the USA may be attributed to the enforcement of stricter workplace codes (Mudarri 2010: 16). Simone *et al*. (2013: 1007) reported an airflow rate from 0.14 m/s to 0.41 m/s while the present study has a range of 0.06 m/s to 0.42 m/s in casual and QSR, respectively. However, Simone *et al*. classified kitchens based on food service operations and not according to heat loads. Nevertheless, the comparison remains relevant as both investigations are in commercial kitchens and not residential kitchens (Tables 8.4 and Appendix 11).

Table 8.3 Airflow range in kitchen areas

Kitchen area	Mean	Median	N	Std. Deviation	Minimum	Maximum	Range
Receiving area	0.33	0.10	31	0.58	0.00	2.00	2.00
Preparation area	0.29	0.10	32	0.32	0.00	1.00	1.00
Stove	0.27	0.10	31	0.39	0.00	2.00	2.00
Oven	0.10	0.10	31	0.15	0.00	0.50	0.50
Holding	0.15	0.10	33	0.15	0.00	0.50	0.50
Dishwashing area	0.08	0.00	32	0.13	0.00	0.40	0.40
Corridor	0.47	0.20	33	0.65	0.00	2.50	2.50

About 56 % of the workers complained in Table 8.4 that ventilation was inadequate in the kitchens; airflow rates ranging from 0.0 to 0.63 m/s were recorded. The dissatisfaction concurs with Simone and Olesan (2013: 1) where more than 60 % of kitchen workers requested more air movement.

As recorded in Table 8.3 (page 205), some kitchen areas had nil airflow. However, only 27 % of the kitchen workers complained that airflow was inadequate during peak periods as they reported stuffiness, especially during summer. Odours and stale air were reported by 2.9 % and 2.3 % respondents in kitchens 11 and 22 respectively, at times during cooking. Thirty-three percent (33 %) of workers opined ineffective ventilation (Figure 8.4) and almost 12 % of head chefs (Appendix 12**)** considered ventilation to be inadequate. Moreover, kitchen 11 and kitchen 17 had hoods installed high in the ceiling with a distance greater than 60 cm (70 cm) leading to staff complaints of odour and stuffiness. A minor proportion (5.3 %) of kitchens had equipment producing soot as grillers and ovens were soiled and scheduled for clean-up. As per Rainbow International (2020: 2), exposure to smoke and soot can adversely affect the health of kitchen workers. Proper ventilation practices are necessary to protect and restore indoor air quality. Soot contains toxic particles leaving behind bad odours and stains (Puro Clean 2018: 2). However, almost 58 % of the kitchens had equipment that did not produce soot from burning of spills or unclean equipment.

A novel fats, oils and grease (FOG) reduction technology utilising a reagent containing Bacillus subtilis is highly adaptable to a great variety of kitchens. The duct temperature was reduced by 7 °C and odour issues were controlled (Mudie and Vahdati 2017: 35) which can be looked into.

Figure 8.4 alludes to the need for air exchange. Exchanging stale air for fresh air that expels humid and odorous air from kitchens (Clausing 2015: 1) are key aspects of ventilation. At low temperatures, airspeeds <0.1 m/s tend to cause a sensation of staleness and stuffiness (Bridger 2003: 254) as indicated in Appendices 11 and 12. Yan *et al*. (2020: 1) report that airspeeds of more than 1.0 m/s have a cooling effect in the air temperature above 33.5 °C in hot-humid regions. Zhai *et al.* (2015: 178) recommend airspeed of 1.2 m/s at 30 °C with a relative humidity of 80 % which exceeded the upper limit set in the ASHRAE Standard 55 (0.8 m/s).

The present study recorded mean airflow at hoods ranging from 0.1 m/s to 1.5 m/s. It was not possible to measure the airflow at hoods in all the sampled kitchens as it could endanger the researcher**.** Different configurations and specifications of hood can impact the ability to capture and contain effluent, including odours, gases, heat and oil. EASHW (2008: 72) reported that poor ventilation, bad smells and toxic substances in the air-smoke are a considerable problem in the catering sector. Except for staff in one kitchen, there were complaints from staff from all other kitchens about excessive heat in the kitchens (Table 7.17 page 173). A greater number of concerns were expressed among those staff in kitchens with no vent, diffuser, or air-conditioner in the kitchens.

Almost 67 % of the kitchen managers assumed that the cooling sources in the kitchen were adequate. However, 33 % of head chefs responded that it was inadequate and were supported by a larger 45% of kitchen workers who also thought thermal environment vary seasonally, and 41 % of kitchen staff found the thermal environment uncomfortable.

Laikko-Roto and Nevas (2014: 67) found that ventilation of kitchens and dining areas in Finland scored 7.0 (55/56) and 8.7 (81/82); p =¼ 0.000* with the food control officials and restaurant owners, respectively. School food services located in rural areas had lower compliance rates for ventilation in Brazil (Almeida *et al*. 2014: 349).

Of the sampled kitchen workers, Figure 8.4 commented that the air was clean. This is despite several kitchens showing zero airflow in different areas, triggering stuffiness and high humidity in dishwashing areas. These findings are consistent with studies by Li *et al*. (2012: 139), Saha *et al*. (2012: 183) and Simone and Olesan (2013: 1) who found that different areas in kitchens have altered airflow rates due to differential air movement resulting from NV, location of air diffusers supply and layout. If parts of the kitchen have always had no or low airflow and staff have not been comfortable, it is usually the result of an inadequate duct system installation when the kitchens were built or the equipment replaced (Pipping Brothers 2015: 1).

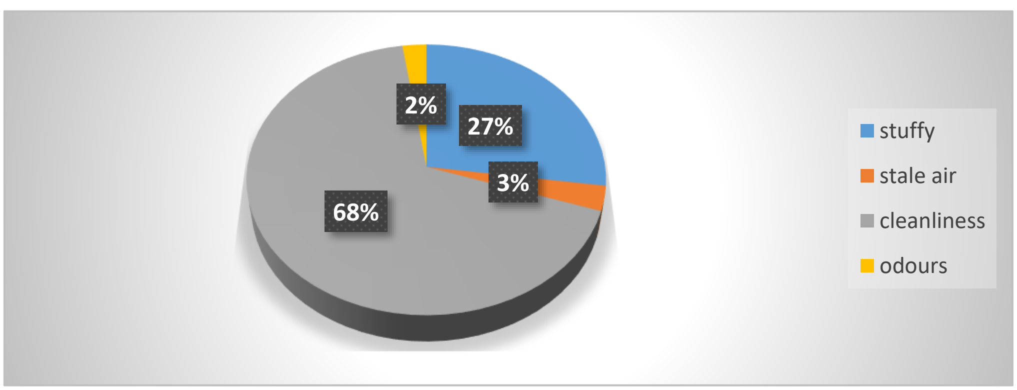


Figure 8.4 Kitchen workers opinion about peak period airflow

8.3.1 Draft in the kitchens

In actual kitchen conditions, disturbing drafts may arise from cooking behaviour, movement of people, open windows, doors and makeup air systems (Han *et al*. 2019: 1). Domestic and heavy-duty fans were the source of air movement in 35 % of kitchens that push thermal plume into the cooker hood along with NV. However, when not installed directionally correctly, the draft results in spilt heat, emissions and CO_2 from the poorly installed hood into the rest of the kitchens as observed in kitchen 21, kitchen 29 and kitchen 33. Staff in the sampled kitchens sometimes complained about hot drafts and hot environment.

Timerbaeva (2010: 39) comments that location of delivery doors, service doors, pass-through openings and drive-through windows can also be sources of cross drafts and concurs with Swierczyna and Sobiski (2003: 21) that high air velocities aided by drafts disrupt thermal plumes, hence diminishing the efficacy of the hood with drafts and make staff feel uncomfortable. Higher air movement can be desirable for cooling in hot conditions, however, thermal discomfort can be caused by cool draft as well (Sansaniwal *et al*. 2020: 1303). Kitchens 12, 13 and 16 had large industrial fans that ran on maximum speed of 1 400 rpm causing drafts. Staff sometimes complained about hot drafts and hot kitchens. Alexandrova (2009: 9) posits that lower speed of fans take heat straight into the hoods because there is less air disturbance, and draft due to reduced speed of supply air coming into the kitchen. Li *et al*. (2012: 145) support this argument. The sensation of draft was lower in kitchen activity areas and workers felt warm. The author further found that cold supply air flowed directly to the heads of the chefs, causing discomfort.

Kitchen 22 had a functioning air cooler provided with closed windows in the preparation room in a humid kitchen, which increased discomfort among workers. Air coolers operate best in dry weather conditions (Calitraba 2018: 1). When used indoors, air coolers require a natural outlet for fresh air such as an open door or window.

By means of MV diffusers it becomes a challenge to supply large amounts of fresh air without creating local discomfort for occupants (Mikeska and Fan 2015: 1). A similar problem is reported in Li *et al*. (2012: 139). This was prevalent in kitchen 3 where the air supply inlet installed at 2 sides of the extractor duct caused plume spillage from the sides of the duct and air impurities spread throughout the kitchen. The air supply outlet spilled air directly onto the heads of chefs causing discomfort. Using exploratory factor analysis, a factor loading of 0.876 for difficulty in breathing and was categorised into component 1, Discomfort (Table 8.4 page 209). The head chefs opined that only 2.9 % of staff complained often about difficulty in breathing. The study further revealed chi-squared values of 66.235. Since p= 0.000; there was strong evidence to conclude that the variables are associated.

Table 8.4 Factor analysis of ventilation factors

Q43	1 Discomfort	2 Uneasiness Factor	3 Maintenance	4 Kitchen Layout
12. The staff complained about humidity in the kitchen	0.268	0.708	0.055	-0.011
13. The staff are content with airflow in the kitchen	0.052	-0.144	0.155	0.866
14. The staff complain of hot /cold draft in the kitchen	0.617	0.227	-0.215	0.097
15. Staff complain about difficulty in breathing	0.876	0.426	-0.012	-0.001
16. All kitchen equipment is installed as per specification	-0.160	-0.057	0.693	0.134
17. Staff complain that it is too hot in the kitchen	0.090	0.844	0.072	-0.098
Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.				
a. Rotation converged in 5 iterations.				

Emissions from food preparation can spread to other parts of the kitchen. The correlation between staff complaints about difficulty in breathing (kitchens 11, 23 and 28) and staff complaints of hot drafts in the kitchen was statistically significant, $r(33) = +.568$, $p < .001$, two-tailed. About eighty-four percent (83.5 %) of staff never complained about difficulties in breathing. Juntarawijit and Juntarawijit (2017: 1) reported that almost 22 % of kitchen workers suffered inter alia from shortness of breath due to exposure to toxic compounds from burning of fuel and fumes from cooking. Gul (2011: 97) stated that difficulty in breathing can be a symptom of SBS. Azreen *et al*. (2012: 100) reported that 16.7 % of paper workers in Malaysia had breathing difficulties. The correlation between staff complaints about difficulties in breathing and staff complaints about humidity in the kitchen was statistically significant, $r(33) = +.561$, $p < .001$, two-tailed. IAQ is influenced by cooking styles where air pollutants generated by cooking could build up to the levels that are harmful to human health (Lee *et al*. 2001: 191).

8.3.2 Preventing drafts

Draft management involves the inflow-outflow rate. Caple (2018: 4) posits that all extractor hoods remove emissions and humidity; to ensure that the thermal plume rises vertically up for extraction and are not disturbed by the inbound air, steady air circulation must be provided in the kitchen and intrusive cross-flows must be avoided. Halton (2007: 32) argues that opening windows in the kitchen creates drafts and also affects the ideal shape of the thermal plume.

About seventy-four percent (73.5 %) of the staff never complain of hot/cold draft in the kitchen. Some staff at times complained about hot drafts in kitchens 13, 16 and 23 as the movement of air from fans could have disturbed the thermal plume before entering the extractor if it was not fitted directionally accurately. This is reiterated by Clark (2009: 21) who further argues that a revision of location and better choice of supply air outlet can reduce draft. Kitchen 6 had perforated perimeter supply (PPS) that cooled the chefs without any draft.

8.3.3 Uneven airflow

The corridors leading to study kitchens 6 and 7 showed higher flow rates from open doors with NV and air-conditioners in the restaurants, near the kitchen entrance**.** Kitchen 6 had PPS installed above a range as well and kitchen 7 had a large corridor to air movement and distribution. Five kitchens - 3, 7, 14, 19 and 13 had favoured hybrid ventilation with airflow rates from 0.3 m/s to 2m/s due to sea breeze. Such higher flow rates while seemingly better for ventilation has come under criticism. A Finnish study (Shah and Dufva 2017: 6) argues that a higher airflow rate does not necessarily help to remove pollutants from the kitchen environment. Instead, a lower airflow rate helps with proper mixing of the air and contaminant removal with a lower energy cost. Amongst others, the present study indicated that the use of spot cooling fans, air-conditioning, general ventilation, and local exhaust ventilation at points of high heat production while influencing the health and comfort of kitchen workers, could simultaneously cause uneven airflow. Even though Almesri *et al*. (2013: 621) adapted the Bedford 7-point scale to the extended 9-point scale for a new Air Distribution Index (ADI) to assess the ventilation performance in thermal environments, its applicability in kitchens is questionable.

8.3.4 Extractors and airflow

The NV from fenestrations and other mechanical means, as evident in Table 8.1, when combined with HVAC systems observed in all the kitchens, create dilute ventilation and MM ventilation. During summer months, heat and humidity were severe as cold air was not pumped into kitchens lacking air-conditioners or diffusers. Although, only 11 kitchens had air-conditioners, air curtains, ceiling diffusers and or air coolers to assist with temperature control to cool the sampled kitchens, and assist in circulating air in non-cooking areas, the health and comfort of kitchen workers did not seem to be affected. Kosonen (2014: 2) and Li *et al*. (2012: 146) warns that without mechanical cooling, the air temperature in the kitchen can get above 30° C during summertime; high contaminant removal efficiency is critical in the front-cooking or open-plan kitchen where the actual cooking happens close to the customers. Cooking areas had an airflow rate ranging from 0.1 to 2 m/s. Even though 54 % of the kitchens continue to run the extractor for a short while after the cooking process, 9 % reduced the extractor speed. This practice is challenged by Dobbin *et al.* (2018: 286) and Sjaastad (2010: 53) in stating that extractors must run at maximum for a short time after cooking to exhaust heat and pollutants efficiently.

The opinion of head chefs denote that 11.8 % of the kitchens had workers who were discontent with airflow. In addition, 35.3 % of the head chefs claimed that staff were content with airflow all the time (Appendix 12) with a chi-squared value of 7.471 with p=0.020. The present study observed that the kitchen canopy hoods are wall-mounted or island hoods with a mean airflow rate of 1.77 m/s. Clark (2012: 60) asserts that velocity above 13 m/s creates objectionable velocity noise. Evidently, that poor airflow rates and no airflow in some sampled kitchen zones have caused dissatisfaction with ventilation and the maximum airflow rate being 2 m/s which is far less than Clark's assertion to create noise.

Table 8.5 Extractor sizes of the sampled kitchens

Extractor measurements (metre)	**Mean**	**Median**	**N**	**Std. Deviation**	**Minimum**	**Maximum**	**Range**
Length of extractor hood	4.84	4.55	32	2.46	2.10	14.07	11.97
Width of extractor hood	1.60	1.30	33	0.83	0.19	4.22	4.03
Number of enclosed sides	4.45	5.00	31	0.72	3.00	6.00	3.00
Number and size of grease filters	9.84	8.00	31	6.54	0.00	26.00	26.00
Adequate duct sizes and numbers	1.46	1.00	30	0.79	1.00	4.00	3.00
Canopy overhang	0.60	0.61	30	0.38	0.06	2.00	1.94
Number of HVAC extractor	1.77	2.00	33	0.43	1.00	2.00	1.00

The length of extractors varied from 2.10 m to 14 m, the maximum observed in a casino complex kitchen; the width of canopy hood ranged from 0.19 m over a conveyer toaster to 4.22 m for a double island for a ranch style family restaurant kitchen (Table 8.5).

Kitchens 7 and 31 had a good alignment of a hood with cooking equipment and a hood lip extending beyond the end of cooking equipment with length varying from 2 m to 14 m and width ranging from 0.19 m to 4.22 m. Conversely, some of the overhangs were extremely small, 0.06 m due to the Chinese design: the maximum being 2 m including the depth of extractor hood. More than 40 % of overhangs were less than 0.06 m, 12 % overhangs were only 0.10 m long. The hood overhang of 0.1 m is the requirement stipulated (Zhang *et al.* 2020: 171). It was estimated that the duct sizes were adequate for the extraction of emissions as all ducts were not visible. The size of the extractors seemed to be adequate except in two kitchens, as cooking equipment extended beyond the hood length and had upper side arrangement which is common; the exhaust air ducts with a diameter of 0.40 m were connected to openings above the ceiling. HVAC extractors are only installed in the cooking zones and hence extractor size and location could not be cross tabulated with airflow rates at different kitchen zones.

These measurements echo Kuehn's *et al*. (2009: 362) findings who report that a commercial kitchen extractor was 2.44 m long by 1.22 m wide, Type I, wall-mounted canopy. Zhao *et al.* (2013: 144) also observed differences in traditional Chinese style cooking hoods with affect exhaust efficiency because of the small hood volume.). Hueda (2020: i) reports that the main problem found in kitchen hoods is the inadequate exhaust airflow; the minimum required airflow varies depending on the size and shape of the hood. The author further recommends that if the performance of the kitchen hood is not good enough yet, an inclined air curtain may be installed due to their great effectiveness against problems of hoods.

The American or European style hoods have cuboid hoods wherein volume is calculated by the length of the overhang. Allen (2014: 2) recommends that the efficiency of a hood can be maximised by placing cooking appliances as close to the wall as possible and ensure that the entire cooking area is covered by the hood. Chandler (2019: 2) suggests that the hood be installed between 61 cm and 76 cm from the stovetop. Many hoods are simply installed too high and this drastically reduces their effectiveness. Placing the hood at a distance far above the appliance increases opportunities for leakage of thermal plume that dissipates quickly with an increase in distance (Han *et al*. 2019: 8Mixed-mode ventilation

Babu and Suthar (2020: 139) assert that there is a scope for improving the IAQ and thermal comfort by implementing proper natural and MV with air cleaning. Almost 79 % of the sampled kitchens had natural ventilation incorporated along with mechanical devices and extractors. MM ventilation can be used to maintain indoor air quality and internal thermal temperatures year round using both natural and MV systems (ASHRAE 2019: 5). Parkinson *et al*. (2020: 1) claim that a MM design can minimise HVAC energy demand without compromising occupant thermal comfort. Five kitchens - 3, 7, 14 19 and 13 had a good balance of natural and mechanical ventilation. The principles of hybrid ventilation were well applied where it combined the best of natural and mechanical ventilation. The combination of large corridors, high ceilings and open doors permitted sea breeze.

The kitchens maintained ambient temperatures of less than 30º C with relative humidity of 55 % with extractors assisting during cooking mode. The airflow rates varied from 0.3 m/s to 2 m/s due to sea breeze that diluted pollutants; CO_2 levels measured were less than 600 ppm in all areas of the kitchen. Hong *et al*. (2007: 432) find that the relatively clean air from the sea effectively diluted the polycyclic aromatic hydrocarbons (PAHs) from residential cooking source in Xiamen. Similarly, Mohr *et al*. (2012: 1661) report that organic aerosols produced from cooking indoors is significantly diluted by the sea breeze in Spain. Van Hoof *et al*. (2017: 127) claim that a balanced mix of passive, architectural solutions and active technological solutions is ideal. The ratio of NV and MV is beyond the scope of this study.

8.4 Air quality

Restaurant workers are at risk from exposure to toxic compounds from burning of cooking fuel and fumes (Juntarawijit and Juntarawijit 2017: 1). Forty-six percent (46 %) of the workers complained about smoke and fumes during rush hour in cooking zones (Figure 8.6).

Appendix 12 indicates the head chefs' opinion on the adequacy of ventilation and hence on air quality in kitchens. The relationship between kitchen worker's perception of ventilation in their kitchen-(inadequate/ satisfactory) and fondness for Durban weather was statistically significant, (n=170), $p < .014$, two-tailed (Appendix 24). Just over fifty-six percent (56.1%) of the workers reported that ventilation was inadequate, affecting the air quality negatively. The mean airflow rate measured was between 0.08 m/s to 0.47 m/s in dishwashing areas and corridors, respectively.

Zhao *et al.* (2014: 545) and Shah and Dufva (2017: 14) have indicated that Chinese kitchens have poor IAQ due to the type of cuisine, different styles of cooking, method of cooking and equipment used. However, Yang *et al.* (2021: 2) observed that the airflow rate of kitchens required by the Chinese standard is higher than that of ASHRAE standard and England Building Regulations.

According to Downing (2008: 6), an increase in deadly CO fumes from solid fuel cookers, barbecues and pizza ovens is endangering the health of commercial kitchen staff. Also, the concept of placing layers of 'volcanic rock' on top of traditional gas grills has created harmful emissions declining the quality of air as observed in ranch style family restaurant kitchens 25 and 26 of the sampled population.

8.4.1 Effect of cooking methods on air quality

The discussion of several authors in section 3.9.2.3 including Lee and Gany (2013: 649) found high levels of pollutants in commercial kitchens, in which frying and grilling were common cooking methods**.** Ninety-four percent (94 %) of the food service operations sold fried food. Forty-eight percent (48 %) of the kitchens filtered the oil every day and 13 % of the kitchens changed the oil every day. The most common practice observed was to filter oil three times/week and change to fresh oil twice/week (Figure 8.5). Srivastava *et al.* **(**2010: 1343) endorse that consumption of repeatedly heated coconut oil (RCO) by frying can cause adverse health effects. The frequent filtering of oil and change of oil improves kitchen air quality due to lower emissions as fast and frequent filtrations will improve the quality of oil (Henny Penny 2020: 2). Air quality in kitchens is affected due to emissions from the breakdown of fried oil which causes cooking fumes containing carcinogens and particulate matter (Dai *et al.* 2018: 315). Measuring the composition of fumes is beyond the scope of this study.

As in other studies, the current study observed diverse cuisine and cooking methods. Zhao's *et al*. (2019: 1953) found that the composition of cooking aerosol particles is highly diverse, depending on the fuel type, cooking oil and temperature, cooking method and style, raw ingredients as well as other factors. The researcher observed that frying produces a lot of emissions and moisture that can add to the humidity levels causing stuffiness (Appendix 14 and Figure 8.4). Emissions in a kitchen can also vary day-to-day because of fuel characteristics such as moisture content, airflow, type of food cooked, or if the kitchen uses multiple stoves or fuels (Ezzati and Kammen 2002: 1057). Singh *et al*. (2016: 2) and Zhang *et al.* (2010: 1744) confirm this and the latter adds that cooking methods such as frying, roasting, grilling, boiling and broiling and cooking style and raw ingredients contribute to pollutant emissions.

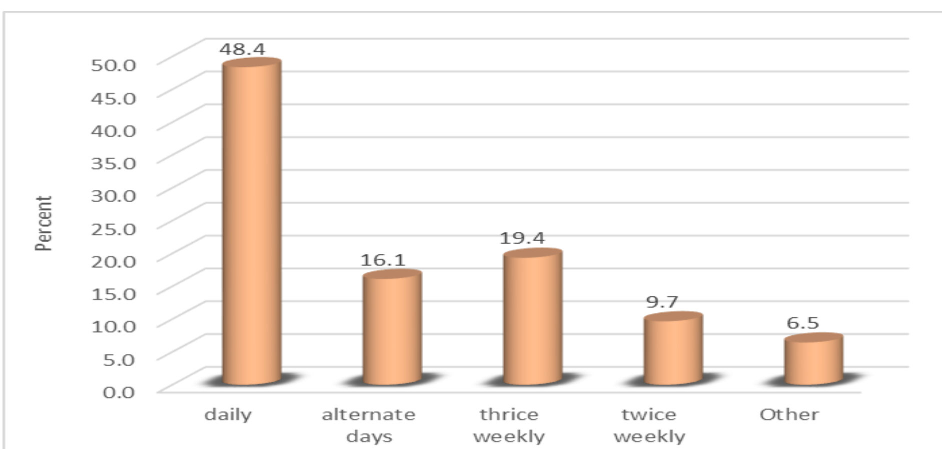


Figure 8.5 Frequency of filtering frying pan oil

Heavy-duty kitchens had the highest CO_2 concentrations near grillers, more than 1 000 ppm. Among all the different equipment used, gas grillers or char-broilers seem to generate the most emissions. Six kitchens-13, 20, 23, 24, 25, and 27 had CO_2 levels > 1000 ppm near grillers. The mean differences in CO_2 levels near grillers in medium and heavy-duty kitchens was 170 ppm and 116 ppm, respectively, higher than stoves (Table 8.6). Jiang *et al.* (2012: 4435) reported CO_2 levels more than the acceptance criteria (CO_2 < 1 000 ppm) near stoves. This has a serious impact on the staff's physical health. On the contrary, Lee *et al.* (2001: 181) claim the maximum levels of CO_2 were linked with the baking process, higher than grilling because of the very high temperature needed for baking. However, the sampled kitchens reported 440 to 770 ppm for electric ovens.

Table 8.6 Cuisine and CO_2 levels (ppm)

Zone	Fusion	Continental	Contemporary	Fast-food	Oriental	Indian	Italian
Preparation (n=33)	544.6	478	527.4	491.5	593.5	**760.6**	557
Stove (n=31)	807.2	503	738.5	0	**875.5**	850.6	785.14
Oven (n=21)	644	491	0	465	0	**983.25**	557.16
Griller (n=14)	1014	0	**920**	638.25	0	0	863
Fryer (n=31)	596.66	0	603.5	**740.5**	514	0	519
Dishwashing (n=33)	509.2	491.5	546	480	580.5	**734.4**	475.8

"0" indicates absence of equipment or unused equipment

8.4.2 Carbon dioxide levels indicate air quality

Mishra *et al.* (2020: 440) claim that building ventilation standards use indoor CO_2 levels as a proxy for air quality. Singh *et al*. (2020a: 125) posit that CO_2 concentration acts as an important indicator of IAQ; levels above 1000 ppm inside a building indicates insufficient ventilation, which may affect the health and impair concentration and performance of occupants. Babu and Suthar (2020: 140) who assert that there is a relationship between IAQ and the ventilation rate reinforce this conclusion; a good IAQ is attained by satisfactory ventilation with fresh outdoor air. The researcher contends that unsatisfactorily high concentrations of CO_2 inside commercial kitchens are likely to be attributed to blocked filters in a hood or insufficient fresh 'make-up' air being introduced which is a precarious situation.

Measures of CO_2 levels in the present study ranged from 401 ppm to 2517 ppm in different restaurant kitchens. Seventy percent (70 %) of the kitchens were within the ANSI (Petty 2014: 2) and ASHRAE 62 (1989) guidelines of 1 000 ppm (Appendix 13) whereas 80 % of the different kitchen areas had CO_2 levels below 800 ppm (Table 8.7 page 216).

Table 8.7 Mean CO2 levels (ppm) in kitchens

Kitchen zone	Mean	Median	N	Std. Deviation	Minimum	Maximum	Range	Kitchen 12
Receiving	528.31	481.00	29	203.88	403.00	1488.00	1085.00	834
Preparation	562.47	510.50	32	164.70	420.00	1210.00	790.00	840
Stove	838.39	823.00	31	354.69	432.00	2155.00	1723.00	899
Oven	691.60	623.00	30	226.64	435.00	1229.00	794.00	844
Holding	562.68	502.00	31	153.07	431.00	1135.00	704.00	852
Dishwashing	557.93	513.00	30	151.86	404.00	1215.00	811.00	836
Corridor	506.16	465.00	31	133.46	401.00	1086.00	685.00	753

Grillers had the highest mean of 996 ppm for CO_2 and corridors areas towards the kitchen had the lowest average value of 506 ppm for CO_2 (Table 8.7). These results are comparable to the study of restaurants by Akbar-Khanzadeh *et al.* (2010: 640); the mean levels of CO_2 in two restaurants (646 and 819 ppm) were <1000 ppm, and in the other six restaurants (ranging between 1012 to 1820 ppm) it was >1000 ppm. Kitchen 23 had high CO_2 levels ranging from 1085 to 1488 ppm in all areas of the kitchen and had a good workflow plan without any consideration for air displacement. None of the kitchens had CO_2 detectors as recommended by IGEM (2015: 7). Kitchens 11, 17 and 18 had higher CO_2 levels of 899 ppm, 1246 ppm and 1016 ppm due to canopy hoods at greater heights above gas stoves whereas kitchen 12 had higher levels as cooking equipment extended beyond the hood length. Allen (2014: 2) recommends that the entire cooking area is covered by the hood. Shorter overhangs of 0.10 m could also lead to higher levels of CO_2 in these kitchens as 42 % of overhangs were less than 0.06 m, 12 % overhangs were only 0.10 m long.

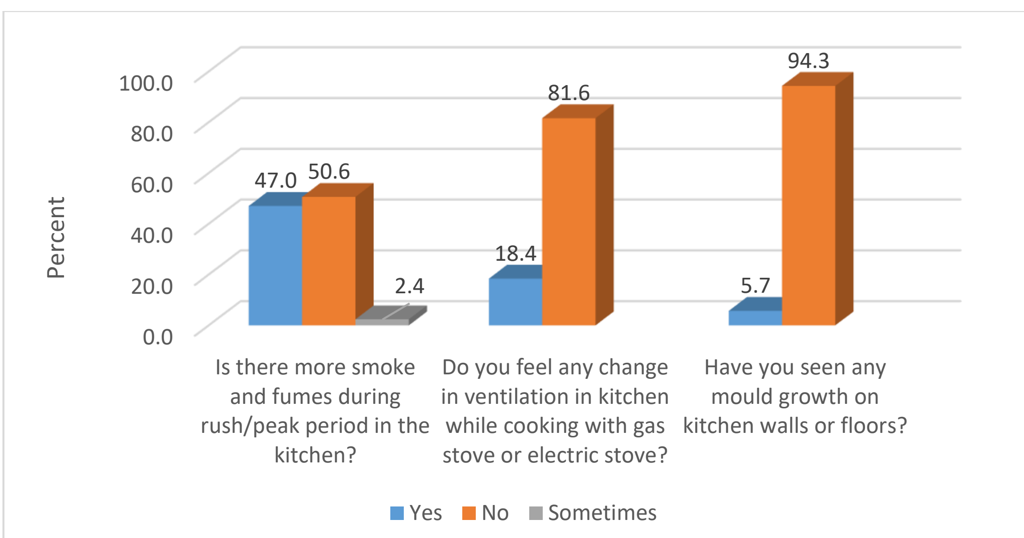


Figure 8.6 Kitchen workers opinion on fumes, gas stoves and moulds

Comparison of different variables observed in prior research elicits several similarities to the current study. Saha *et al.* (2012: 183) found associations between temperatures across the different kitchens and CO_2 emissions. The temperature varied from 25 °C to 38° C at a height of 0.6 m from the floor and at a distance of 0.1 m from burners. Li *et al*. (2012: 150) agrees with the concept that the increase of CO_2 concentration follows an increase in temperature. CO_2 controls the amount of water vapour in the air and thus the temperature levels (NASA Earth Observatory: 2011). A higher ambient temperature range could be due to higher outdoor ambient temperatures. India has a tropical climate and in summer the temperature soars. It can be noted that the increase in temperature corresponds to an increase in CO_2 levels. Results of sampled kitchens (Table 8.7 page 216) concur with Saha *et al.* (2012: 183) and Li *et al*. (2012: 150); zones near grillers and gas stoves cook at higher temperatures and produce higher CO_2 levels. CO_2 levels were high (>1000 ppm) near grillers and tandoors in 30 % of kitchens and this could be due to ineffective HVAC system caused by inadequate extraction and airflow. Kitchen extract ventilation should be re-classified as ‘Local Exhaust Ventilation’ (LEV) to protect catering staff from increasing threats to their health (Downing 2008: 6). Measuring the volume of exhaust flow is beyond the scope of this study. Han *et al*. (2019: 2) requested that high-performance ventilation systems and exhaust hoods are required to reduce pollutants and maintain good IAQ in kitchens.

8.4.3 Effect of kitchen loads-fuels and cooking equipment on air quality

The use of electricity instead of LPG for cooking produces a healthier and a comfortable environment for kitchen workers as the gas stove is considered to be a source of heat and air pollutants (Leitner and Kajtar 2018: 30). Gas stoves could be gradually phased out, in favour of induction cookers, which are reportedly as effective for food preparation but were found only in 6 % of the sampled kitchens and these stoves are a new trend to reduce heat in the kitchen. Only two pizzerias had no stoves at all as cooking requires only ovens.

Eighty-eight percent (88 %) of kitchens adopted non-pressure/low-pressure gas stoves. Gas pressure stoves are popular in authentic Indian kitchens due to heavy-duty cooking. Wok stoves measured as heavy-duty equipment are gas pressure stoves that cook at temperatures of 315 °C. Gas-fired kitchen ranges release unvented combustion products into the kitchen. CO concentrations in the kitchen are elevated when the stove is used without using the extraction hood (Greiner 2020: 1).

According to Jha (2005: 1), pizza ovens are a major source of pollution. The future of wood-burning pizza ovens in Italy looked doubtful as laws came into force limiting the amount of pollution that can be produced. Povoledo (2016: 1) reported that to decrease air pollution, an ordinance was issued banning the use of wood-fired stoves not equipped with filters. More than 90 % of the sampled kitchens had an oven. Electric ovens were most commonly used and 90 L was a popular size that was installed in 9 kitchens; it can generate temperatures of 204° C to 232° C. Wood-fired kiln pizza ovens are considered as extra-heavy-duty equipment generating heat of 371° C were more popular in restaurants whereas electric pizza ovens were popular in takeaways. Different kitchen zones with varying ventilation load had fluctuating CO_2 levels (Table 8.7). Besides heat and humidity, emissions from fuels specify kitchen load.

Table 8.8 Mean CO_2 level (ppm) in kitchens with different heat output

Areas	Light	Medium	Heavy	Extra heavy
Receiving	442	481	561	459
Preparation	463	503	571	658
Stove	0	531	1114	672
Oven	459	476	985	647
Griller	0	678	1230	0
Fryer	0	535	798	581
Holding	467	620	595	647
Dishwashing	490	482	583	516
Corridor	425	457	543	473

"0" indicates absence of equipment or unused equipment

According to ASHRAE 62.1 (2013:17) and the US International Mechanical Code (IMC), kitchen loads are classified based on the type of equipment and fuel used in the kitchen operations are highly pertinent to the type of cuisine. The ventilation systems are designed for heat output from the cooking appliance as there is a large variation in the cooking effluents in different food service operations (FCSI 2006: 7). Although the use of biofuels was found to be uncommon, gas grilling was observed in 27 % of the kitchens including 8, 11, 13, 20, 22, 24, 25, 26, 27; higher emissions of CO_2 was evident amongst heavy-duty load kitchens (Table 8.8). Gas stoves also contributed to increased CO_2 levels in these kitchens' cooking zones. Light-duty load kitchens had the lowest CO_2 levels, however, besides cooking activities, it seems the presence of CO_2 in the kitchens is affected by the efficiency of extractors, drafts and the layout.

$Y_{predicted} = b0 + b1*x1$

The column of estimates provides the values for b0, b1 and b2 for this equation.

The equation: CO_2 near stoves = 1422.37 + (- 359.179 x floor is dry)

Natural ventilation – the coefficient for NV is -12.068. So, for every unit increase in NV, a -12.068 unit decrease in CO_2 near stove area value is predicted, holding all other variables constant (Table 8.9). All the kitchens under study had dry kitchens. Chang *et al*. (2012: 366) reported that in the majority of Korean food service settings the floor remains wet with little consideration to keeping its floor dry in facility design. Dry kitchen has special design points that allow the floors to remain dry. Combustion products from the LPG release a high quantity of water vapour that is not a direct health concern but can contribute to high indoor humidity (Kim *et al.* 2018: 1). Wong *et al*. (2011: 747) found concentration of CO_2 was 29 % higher in gas-burning kitchens than in electric kitchens. Higher humidity levels in kitchens will hinder drying of wet floors. Less use of gas as fuel means less CO_2 released and less humidity in kitchens.

Table 8.9 Analysis of variance for CO_2 and independent factors

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	1422.378	312.890		4.546	0.000		
	Natural ventilation	-12.068	65.025	-0.036	-0.186	0.855	0.972	1.029
	Floor is Dry / semi-wet / wet	-359.179	143.352	-0.486	-2.506	**0.021**	0.972	1.029

a. Dependent Variable: CO_2 near stoves DA102.3

b. Predictors: (Constant), Floor is Dry/semi-wet/wet, Natural ventilation BC64

Therefore, the wet floors will dry faster. Similarly, for every unit increase in dry floor, we can expect a 359.179 unit decrease in CO_2 near stove areas, holding all other variables constant. Mandal *et al.* (2020: 16) recommend that the frequent cleaning of cafeteria floors may reduce the suspension of dust from on the floor improving IAQ.

The coefficient for NV (-12.066) is not significantly different from 0 because its p-value is 0.855, which is greater than 0.05. However, in this study it was not a significant factor in the model. The coefficient for Floor is Dry (-359.179) is significantly different from 0 because its p-value is 0.021, which is smaller than 0.05. Tests for multi-collinearity indicated that a very low level was present (VIF = 1.029) for dry floors. Beta coefficients for one predictor was floor is dry, β =-359.179, t = -

2.506, $p < 0.021$. The best fitting model for predicting humidity near stoves is a linear combination of floor is dry/wet.

8.5 Humidity

Humidity levels less than 60 % provide an ideal environment in the kitchen (Environmental Protection Agency 2017: 1). A high quantity of water vapour produced can contribute to high humidity and related mould and pest issues (Kim *et al.* 2018: 1). More than 10 % of head chefs felt that kitchens were humid and 15 % felt that it was sweaty in the kitchen.

Appendix 14 indicates mean RH values that are ideally lower than 60 % which could be due to the weather conditions, cuisine and time period of the field study. Boiling foods such as rice, pasta or soup release a large amount of steam increasing humidity (Caple 2018: 18). However, boiling food was unobserved in almost 45 % of kitchens. It was evident that grillers and stove areas have higher mean values for humidity levels, whereas the trimmed mean values were higher for grilling and dishwashing. Johnson *et al*. (2019: 7) claim that a dishwashing room in any food service facility is generally the most difficult and uncomfortable area to work in because of the heat and humidity generated by the dishwashing machine with a 10 °C increase in temperature and 7 % increase in RH due to heat and humidity from the dish machine during operation.

8.5.1 Humidity is affected by cuisine

Humidity can have a profound effect on how food cooks. RH levels varied widely in the sampled kitchens. Cooking areas with stoves had the highest mean value as well as the highest minimum value followed by the dishwashing area. However, ovens produced higher maximum humidity values compared to stoves and dishwashing (Table 8.10).

Table 8.10 Humidity levels in kitchen zones

Kitchen zones	Mean	Median	N	Std. Deviation	Minimum	Maximum	Range
Receiving area	55.67	57.05	30	8.39	38.00	74.40	36.40
Preparation area	55.43	56.90	32	10.16	32.40	77.00	44.60
Stove	**57.48**	**58.50**	32	8.27	**39.80**	74.10	34.30
Oven	56.63	55.60	31	11.70	32.00	**89.50**	**57.50**
Holding area	55.33	55.50	33	8.79	34.60	74.10	39.50
Dishwashing area	57.02	57.80	33	8.75	33.40	75.50	42.10
Corridor	53.64	57.00	33	8.31	31.80	64.20	32.40

8.5.2 Association between type of food service, cuisine and kitchen ventilation load

Lester (2020: 1) posits that humidity can wreak havoc in a commercial kitchen or a bakery. Kitchens are naturally hot environments with higher moisture levels in the air. Improper ventilation increases RH because warmer, moister air collects on kitchen surfaces. A commercial kitchen or bakery should strive for RH of around 60 %. However, there is just too much moisture in the air for some delicate cooking techniques. Clark (2012: 54) confirms that besides heat, smoke and odour even moisture is considered in designing commercial kitchen ventilation (CKV) to be acceptable to the local code authority.

Several close associations were established between the type of food service, cuisine and kitchen load with chi-square tests (Appendix 15). These are identified and explained in the paragraphs that follow. However, the lack of publications on these association hinders discussion. Most Indian cuisine restaurants tend to be heavy-duty or extra-heavy-duty because of the use of LPG or biofuels such as charcoal. Italian cuisines can be extra-heavy-duty due to wood-fired pizza ovens. There is a close association between medium-duty kitchens and QSR with p=0.013; less than the significance level of 0.05, strong evidence to conclude that the variables are associated (Appendix 15). A fast-food restaurant serves fast-food cuisine with minimal table service. The food is typically part of a "meat-sweet diet", from a limited menu, cooked in bulk in advance and kept hot, finished and packaged to order for take away, though seating may be provided (Sharma 2012: 1). The cooking equipment typically consists of electric fryers, grills, griddles and steamers, hence classified as medium-duty unless gas is used as fuel. A medium-duty kitchen would require a minimum exhaust flow rate of 0.094 (m^3/s) for a wall-mounted hood unlisted for adequate ventilation in the kitchen. Livchak *et al.* (2005: 749) claim that if this load is underestimated, the air-conditioning system will be undersized, and it will lack the cooling capacity to reach design temperature in the space, the kitchen will be hot leading to heat illness. Besides the productivity losses, high temperature in a kitchen also contributes to a very high turnover rate.

There is a close association between heavy-duty kitchens and extra heavy-duty kitchens with Indian cuisine in a family restaurant. Local Indian cuisine is cooked on gas stoves and authentic Indian cuisine is cooked with LPG with tandoors using gas/charcoal. These fuels render the kitchens heavy-duty and extra heavy-duty. Haruyama *et al.* (2010: 135) demonstrated that kitchen workers in gas kitchens were subjected to a higher thermal strain than those in electric kitchens and Page (2019: 11) ascertains that the conclusion of this study identifies the difficulties of quantifying thermal strains as commercial kitchens are a complex environment. Logeswari and Mrunalini (2017: 609) reported heat stress among kitchen workers with Indian cuisine. The current study revealed that LPG stoves are popular in authentic Indian kitchens due to heavy cooking. Since p= 0.04 and 0.046 respectively; evidence to conclude that the variables are associated. There is a close association between extra-heavy-duty kitchens serving Indian cuisine in fine dining restaurants. Since p= 0.046; this is strong evidence to conclude that the variables are associated.

A heavy-duty kitchen and extra-heavy-duty kitchen would require a minimum exhaust flow rate of 0.188 and 0.259 (m^3/s) for a wall-mounted hood unlisted for adequate ventilation in an Indian kitchen. According to Singh *et al.* (2016: 2), kitchen workers are prone to heat stress at workplace due to heat generated from cooking practices such as Indian cuisine.

There is a strong association between extra heavy-duty kitchens and Italian cuisine in family restaurants. Pizza ovens using wood as fuel have an extra heavy load in kitchens as wood-fired pizza ovens can be a major source of pollution (Jha 2005: 1). Five of the seven kitchens cooking Italian food had wood-fired kilns; one used a gas-fired tunnel oven and two kitchens had electric ovens as well. Since p= 0.046 there is strong evidence to conclude that the variables are associated. There is a close association between extra-heavy-duty kitchens and Italian cuisine in fine dining restaurants. Due to the presence of wood-fired kilns for pizza, the kitchens require extra heavy load ventilation. Since p= 0.046 there is strong evidence to conclude that the variables are associated. An extra-heavy-duty kitchen would require a minimum exhaust flow rate of 0.259 (m^3/s) for a wall-mounted hood unlisted for adequate ventilation in an Italian kitchen.

There is a strong association between heavy-duty kitchens with fusion cuisine in coffee shops. Fusion cuisine is an amalgamation of different styles of cooking. The equipment and fuel used will depend on the menu items. Since p= 0.016 and less than the significance level of 0.05, there is strong evidence to conclude that the variables are associated. There is a close association between heavy-duty kitchens and fusion cuisine in fine dining restaurants. Gas grilled or char broiled meat offered in the menu of fusion cuisine in fine dining restaurants requires an extra-heavy load in kitchens. Since p= 0.025 the variables are associated. An extra-heavy-duty kitchen would require a minimum exhaust flow rate of 550 cfm per linear foot of hood for a wall-mounted hood unlisted or 0.259 (m^3/s) for adequate ventilation in a fusion kitchen.

There is a close association between medium-duty kitchens and QSR. Since p= 0.013 and less than the significance level of 0.05, there is strong evidence to conclude that the variables are associated. Zhang *et al*. (2010: 3.13) quote that griddles are major cooking equipment in a fast-food establishment and QSR use griddles and fryers 60 % of the operating time which is classified as medium-duty equipment (Clark 2009: 1). There is a close association between medium-duty kitchens and serving a continental menu in a cafeteria. A continental menu refers to lighter European food fare. British refer to the rest of Europe as "the continent" which is a style of cooking that includes the better-known dishes of various western European countries. Since p= 0.025 and less than the significance level of 0.05 the variables are associated. Mandal *et al*. (2020: 10) find that unlike other dining restaurants, cooking is carried out throughout the day in cafeterias increasing RH and PM.

Lu *et al*. (2019: 134) introduced a heat pump to improve temperature and RH in a cafeteria. Earlier the authors reported indoor temperatures of 28.5 °C to 30.6 °C;the WBGT was 28.6 °C -31.1 °C; which is higher than the established comfortable summer temperature of 23.2 °C-27.1 °C in Taiwan. The indoor RH was maintained at around 70.4 % to 88.5 %; this range is higher than the optimal RH of 40 % to 60 %.

There is a weak association between heavy-duty kitchens and Oriental and Thai cuisine served in fine dining restaurants. Oriental cuisine is also served either in QSR or family restaurants in Durban. Stir-frying is a popular cooking method in Chinese/Thai cuisine cooked in a wok at very high temperatures. Oriental cuisine prepares most foods in a wok cooked with gas under pressure at higher temperatures and higher emissions of CO_2 as stir-frying is a popular cooking method. Since p= 0.05 which is equal to the significance level of 0.05, the association is weak.

8.5.3 Humidity around stoves

Parrott *et al*. (2003: 1) claim that moisture is generated in a kitchen through cooking. Hence, humidity is higher in cooking areas near the stoves (Figure 8.7). Partial eta squared between humidity near stoves and type of cuisine is given below in Table 8.11 (page 224). Section 7.6.3 discusses the discomfort index near stoves from humidity in Chapter Seven.

Humidity around stoves (Q91.3)* Type of cuisine: Contemporary (Q12.2), Oriental/Chinese (Q12.4), Italian (Q12.5), Fusion (Q12.7) and other (Q12.8). The effect size is as follows: 0.02 - small effect; 0.06 - medium effect; 0.12 - large effect.

Table 8.11 Association for humidity near stoves

Dependent Variable:						
Source	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**	**Partial Eta Squared**
Q12.2	6.705	1	6.705	0.152	0.703	0.013
Q12.4	14.428	1	14.428	0.328	0.578	0.027
Q12.5	4.555	1	4.555	0.103	0.753	0.009
Q12.7	52.624	1	52.624	1.195	0.296	**0.091**
Q12.8	0.287	1	0.287	0.007	0.937	0.001

a. R Squared = .720 (Adjusted R Squared = .324)

Partial eta describes relationships between variables that determine whether the observed effect is real or attributable to chance and the strength of the relationship between those variables (Maher *et al.* 2013: 345). The results indicate that cooking fusion cuisine has a medium to large effect on humidity whereas cooking Oriental/Chinese cuisine has a small effect. Other cuisine includes the chicken franchise and seafood franchise, which have a very small effect on humidity near stoves.

Zhao *et al*. (2014: 260) report that the biggest increase of RH with hoods in working mode among the Chinese dishes was Kung Pao chicken, as it was 125 % higher than the outdoor value as the marinated chicken is cooked with wine in a wok. The authors further add that cooking in a wok results in a significant contribution to indoor air pollution from emissions which include grease particles, vapour, smoke, products of heat, combustion and moisture. Li *et al*. (2012: 144) reported RH levels ranging from 45.6 % to 79.8 % in kitchens cooking Chinese cuisine.

Using partial eta squared values, it is noted that there is a medium to large effect on humidity by fusion cuisine- Q12.7 ($\eta 2 = 0.091$). Fusion menu offers a variety of items from different cuisines from a kitchen. A fusion cuisine by the same logic is the merging of two disparate cuisines. Fusion cooking is essentially a mixing of food cultures and cuisines (Hamilton 2020: 1). Cooking different cuisines with special appliances can increase humidity especially steaming and boiling. Boiling water will increase the RH in the kitchen (Physics Forum 2015: 1). The problem could be solved by providing very high ventilation rates during the activity periods of cooking and washing using mechanical ventilation. Extract fans are effective measures of controlling the spread of humidity from these zones (Awbi 2003: 74). This study found that humidity was not a significant factor for Indian and Italian cuisine unlike studies by Singh *et al*. (2016: 2) and Logeswari and Mrunalini (2017: 609) where high heat and humidity were associated with Indian cuisines.

This association between independent variables fusion cuisine and dependent variable humidity near stoves helps to compose indoor environmental criteria for design of restaurant kitchens in respect of ventilation and humidity. It has a prediction quality to achieve Objective 1 and Objective 4.

8.5.4 Humidity near stoves affected by worker characteristics

Heinonen (1997: 397) advances that the most uncomfortable workplaces in kitchens are near a frying pan, a stove or a grill because of the heat and humidity from the cooking process. The amount of moisture released in cooking will vary, dependent on the type of food, whether the food is covered while cooking, and the length and temperature of cooking.

Table 8.12 Humidity near stoves is affected by worker shift and their height

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	87.560	13.053		6.708	0.000		
	Height of worker A5	-0.201	0.072	-0.242	-2.784	**0.006**	0.724	1.382
	Worker Shift A13	1.165	0.464	0.186	2.509	**0.013**	0.993	1.007
	Gender A3	-0.365	1.410	-0.023	-0.259	0.796	0.713	1.403
	Race A4	0.634	1.024	0.046	0.620	0.536	0.976	1.025

a. Dependent Variable: Humidity near stoves (DA91.3)

b. Predictors: (Constant), Shift, Height

$\mathbf{Y}_{\mathbf{predicted}} = b0 + b1*x1 + b2*x2$

Humidity near stoves = 92.09 + (1.208 x shift) + (- 0.161 x height of chef)

Cross tabulation among nominal variables from IS and OC revealed that RH which is a dependent (outcome/response) variable, experienced around stoves is affected by the height of the chef and shift work which are independent variables (predictor). Tests for multi-collinearity indicated that a very low level of multi-collinearity was present (VIF = 1.382 for height of worker, VIF = 1.007 for worker Shift). Beta coefficients for the four predictors were height of worker, $\beta = -0.201$, $t = -2.784$, $p < 0.006$; worker shift, $\beta = 1.165$, $t = 2.509$, $p < 0.013$. The best fitting model for predicting humidity near stoves is a linear combination of worker shift and height of chefs (Table 8.12). The other variables influencing humidity in the equation explained below.

Worker shift as explained in section 7.2.8 indicates that the degree of heat exposure in the kitchen is influenced by the worker shift depending on the mealtime. Gas cooking appliances will increase the moisture generated, as water vapour is a by-product of gas combustion (Parrott *et al*. 2003: 1). Heinonen (1997: 398) recommends that humidity levels more than 60 % considered as undesirable. Different areas of kitchen generate different levels of humidity depending on the activities in the kitchen.

With regard to the influence of height (m) of chefs, the coefficient for height of chefs is -0.161. So, for every unit increase in height, a 0.161 unit decrease in humidity experienced near the stove area value predicted, holding all other variables constant. More than 86.0 % of kitchen workers in the sample were <1.68 m tall and almost 52.5 % of kitchen workers were <1.60m tall. It seems that higher humidity experienced by shorter chefs than taller chefs are; this is because a short chef is closer to the stove height. The coefficient for height of kitchen workers (-0.161) in the present study is significantly different from zero because its p-value is 0.036. This p-value indicates that the observed difference or more in 3.6 % of studies be observed due to random sampling error. Simone *et al.* (2013: 1005) similarly found higher levels of humidity at the kitchen worker waist height that reduces as head height is approached.

The International Health Facility Guidelines (2015: 17) recommend that in kitchens, the workbench used for a majority of work in the standing position height is 0.90 m above the floor. These standards apply to Caucasians whose average height is 1.78 m. According to Regatta (2019: 3), a 3-foot or 36″ kitchen countertop is the best or average height for a kitchen. However, the counter heights vary in different countries in terms of physical stature of people. According to South Africa Demographic and Health Survey (2003: 274), mean height for men and women is 1.68 m and 1.59 m, respectively; For most workers, a kitchen countertop height of 1 m (3 feet) provides a comfortable workstation. These design standards are aimed at making things comfortable for average people, who are 1.52 m (5 ft 3 ″) to 1.72 m (5 ft 8 ″) in height (Adams 2019: 2)

Many people of less than average height find 0.81 m (32″) to be a comfortable work-surface height. That means that 86.4 % of kitchen workers in the sample were <1.68 m tall and not comfortable with the standard counter height. More than 52 % of kitchen workers were <1.60 m tall. Regatta (2019: 3) recommends that an ergonomically correct countertop height vary from 0.762 m (30″) for a 1.21 m tall cook to 1.07 m (42″) for a 1.82 m tall cook.

This equation between independent variables and dependent variable humidity near stoves helps to compose indoor environmental criteria for design of restaurant kitchens in Durban in respect of ventilation and humidity. It has a prediction quality to achieve Objective1 and Objective 4. The height of the chef or kitchen workers refers to the phenotype and genotype. It is inferred that Objective 3 is met concerning the appearance of kitchen staff.

8.5.5 Effect of fuels and equipment on humidity

Highest mean RH values of 59.28 % and 58.62 % obtained in cooking areas near gas grillers and gas stoves with trimmed mean values of 52.37% and 51.30%, respectively (Appendix 14). According to Gupta *et al*. (2020: 72), ASHRAE Standard 2013 states that relative humidity maintained between 30 % to 60 %. Hence, a dehumidifier is necessary to take excessive moisture out of the air especially in humid, summer weather (Koncius 2018: 1). Combustion products from the natural gas used for cooking release a high quantity of water vapour that is not a direct health concern but can contribute to high indoor humidity inter alia (Kim *et al.* 2018: 1). These values are in agreement with Li's *et al*. (2012: 144) mean values varying from 45.8 % to 68.4 %. Simone *et al.* (2013: 1008) obtained much lower annual values of 30 % to 44 %, however, the values during summer in moist climatic areas showed values around 64 %. The RH values of sampled kitchens (Tables 8.13 and 8.14) classified according to type of food service were higher than those obtained by the preceding author.

8.5.6 Kitchen humidity and mould

Rosone (2016: 1) theorises that poor humidity control is not just a comfort issue for restaurant kitchens but also causes other problems such as mould growth. According to Leonard (2019: 2), mould may cause symptoms of allergies and SBS with symptoms such as a runny or blocked nose, watery, red eyes, a dry cough, skin rashes, a sore throat, sinusitis, wheezing including shortness of breath. Niculita-Hirzel *et al*. (2020: 10) prove that mechanically ventilated buildings are more effective in preventing the infiltration of outdoor fungal particles when compared to naturally ventilated areas. Wyndham (2019: 1) suggest to enforce policies that make sure that any source of excess dampness such as leaks is addressed promptly.

Mould growth observed in more than 5 % of the kitchens due to excessive humidity and wet floors near dishwashing areas. Fifty-one percent (51 %) of kitchens had 60 % or more humidity levels in one or other kitchen zones but not in all the areas (Figure 8.7). Humidity was high enough to encourage mould growth on kitchen walls and floors (Figure 8.6). However, moisture extraction through HVAC and provision for NV helps to reduce humidity. Extraction systems in professional kitchens remove humidity caused by the tasks of preparing and washing food (Jubany 2010: 3). Seppänen and Kurnitski (2009: 57) suggest a selection of materials that minimise mould and, building materials, equipment and design assemblies that can withstand repeated wetting in areas (kitchens).

Humidity levels less than 60 % provide an ideal environment in the kitchen as Faizal *et al*. (2011: 7) reports that RH ranging from 30 % to 60 % is suitable for thermal comfort. Twelve percent (12%) of the kitchen managers in sampled kitchens agreed that ventilation was insufficient to maintain optimal humidity levels and good air quality. Several authors concur with Kim *et al.* (2018: 1) as discussed in sections 8.5.3 and 8.6.2.1. Ghasemkhani and Naseri, (2008: 63) and (Faizal *et al*. 2011: 7) reported that 90 % of the people felt comfortable with the recommended range for temperature and RH. RH below 30 % results in dry air affects eyes, skin and the mucous membrane while RH above 60 % causes an increase in skin temperature, residual skin dampness and encourages fungi growth that leads to discomfort and an unhealthy environment. High RH and condensation may lead to the growth of mould (Mustafa 2017: 1).

Appendix 14 indicate that mean RH values were below 60 %, however, the maximum values exceeded 60 % and were as high as 89.5 % due to rain. Corridors recorded the lowest RH values due to the absence of sources of moisture generation, better NV and cooled air from restaurants.

Figure 8.6 depicts mould growth in kitchens observed in kitchen 14; the coarse surface of non-slip flooring did not permit mopping. The floor was at a slope to drain spillage automatically. Only 5.7 % of workers had seen mould in kitchens. This sporadic appearance of mould in very few kitchens helps to adapt humidity moderation strategies in different kitchens areas to compose indoor environmental criteria for design of restaurant kitchens in Durban in respect of humidity. It has a prediction quality to achieve Objective 1. Such floor when wet in normal use will not be slippery. However, there have been concerns about the potential for the slip-resistant surfaces adversely affecting hygienic cleaning of floors, resulting in increased food safety risk. In other kitchens, the floors were maintained dry by frequent mopping.

8.5.1 Maintaining humidity levels in kitchen

Increased RH levels increase thermal strain specifically in cooking and dishwashing areas. The lowest RH mean values were recorded in corridors due to the air-conditioners in restaurants. Data on humidity in passageways to kitchens or corridors leading from the dining rooms to kitchen is scarce. Corridors had a mean RH of 52.30 %, even though RH levels ranged from 32% to 74.4 the high value was due to rain during the field study. Nearly 52 % of the kitchen managers claimed that with regard to humidity staff complained about sweat not drying (30.3 %), uniform being wet (12.1 %) and stickiness (6.0 %) (Table 8.14 page 231).

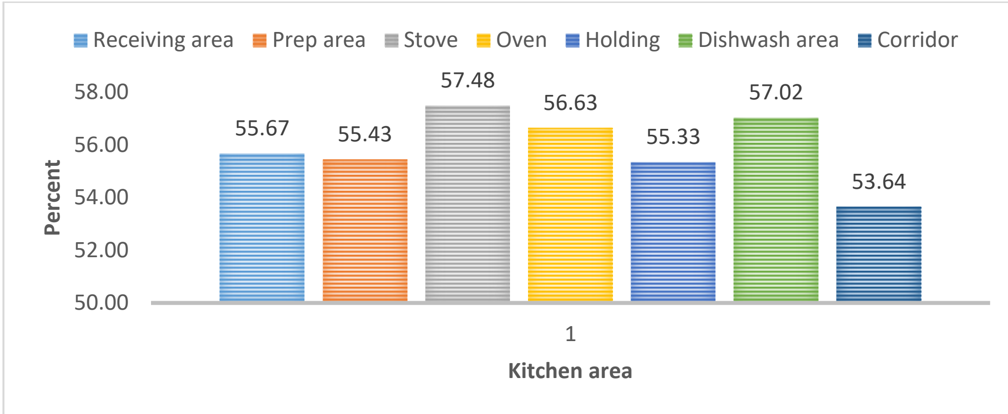


Figure 8.7 Mean humidity levels in sample kitchens

Table 8.13 Humidity near stoves

Coefficients[a]								
Model		**Unstandardized Coefficients**		**Standardized Coefficients**	**t**	**Sig.**	**Collinearity Statistics**	
		B	**Std. Error**	**Beta**			**Tolerance**	**VIF**
1	(Constant)	35.067	8.186		4.284	**0.001**		
	Humidity near Ovens DA91.4	0.327	0.059	0.491	5.542	**0.000**	0.233	4.284
	Humidity in Corridor DA91.7	0.243	0.089	0.242	2.744	**0.017**	0.235	4.255
	Waiting period to repair/replace any malfunctioning equipment	2.186	0.339	0.432	6.451	**0.000**	0.408	2.452
	Air- conditioner	-2.888	0.944	-0.228	-3.061	**0.009**	0.330	3.033
	Domestic fans	-3.614	0.771	-0.395	-4.685	**0.000**	0.257	3.891
	Industrial fans	-0.333	0.393	-0.044	-0.848	0.412	0.679	1.473
	Heavy sweating	-8.908	1.335	-0.460	-6.670	**0.000**	0.384	2.604
	The staff complained about humidity in the kitchen	0.800	0.369	0.127	2.167	**0.049**	0.534	1.874
	Headache	-3.987	1.770	-0.155	-2.253	**0.042**	0.389	2.573
	Intense thirst	4.994	1.330	0.311	3.754	**0.002**	0.267	3.751
	Irrational behavior	-9.181	2.141	-0.296	-4.289	**0.001**	0.384	2.603
	Work experience	-3.529	0.638	-0.300	-5.533	**0.000**	0.623	1.605
	Race	-0.876	0.201	-0.277	-4.361	**0.001**	0.454	2.202
	Heat in Kitchen during peak hours	1.645	0.669	0.134	2.458	**0.029**	0.619	1.616
	Gender	6.617	2.068	0.213	3.199	**0.007**	0.412	2.429
	Decrease of motivation	7.722	2.194	0.249	3.520	**0.004**	0.366	2.733
a. Dependent Variable: humidity near stove DA 91.3								

Alam *et al.* (2019: 4) report that the temperature and humidity during daytime tends to be higher in non-air-conditioned pantry cars as compared to air-conditioned pantry cars in Indian Railways. Matsuzuki *et al.* (2013: 171) installed air-conditioners in hospital kitchens to improve the kitchen environment. A Multiple Regression Equation obtained to indicate which variables really matter to predict humidity near stoves. A long mathematical model (Table 8.13) consisting of several variables including race (ethnicity), mechanical devices for ventilation, physiological and psychological symptoms of heat stress was used.

The following is the equation used: Y = b0 + b1*x1 + b2*x2 + b3*x3 + b4*x4 + b5*x5 + b6*x6 + b7*x7 + b8*x8 + b9*x9 + b10*x10 + b11*x11 + b12*x12 + b13*x13 + b14*x14 + b15*x15

Humidity near stove = 35.067 + (0.327 x humidity near oven) + (0.243 x humidity in corridor) + (2.186 x waiting period to repair equipment) + (-2.888 x number of air-conditioners in kitchen) + (-3.614 x number of domestic fans) + (-8.908 x heavy sweating) + (0.800 x staff complain about humidity) + (-3.987 x headache) + (4.994 x intense thirst) + (-9.181 x irrational behaviour) + (-3.529 x work experience) + (-0.876 x race) + (1.645 x heat in kitchen during peak hours) + (6.617 x gender) + (7.722 x decrease of motivation).

The heat around stoves has a positive relationship with the presence of ovens and dishwashers in the kitchens since p=0.11 and 0.015, respectively; this is strong evidence to conclude that the variables are associated. The heat from ovens and dishwashers contribute to the increase in temperature in the kitchen along with the heat from the stoves was p=0.011 and 0.015, respectively; this p-value indicates that the observed difference or more in 1.1 % and 1.5 % of studies would be due to random sampling error.

Tests for multi-collinearity indicated that a very low level of multi-collinearity was present (VIF = 4.284 for humidity near ovens; 4.255 for humidity in corridors; 2.452 for waiting period to repair/replace any malfunctioning equipment; 3.033 for air-conditioner; 3.891 for domestic fans; 2.604 for heavy sweating; 1.874 for staff complaints about humidity in the kitchen; 2.573 for headache; 3.751 for intense thirst; 2.603 for irrational behaviour; 1.605 for work experience; 2.202 for race; 1.616 for heat in kitchen during peak hours, 2.429 for gender and 2.733 for decrease of motivation. Beta coefficients for three predictors were BMI and type of kitchen, $\beta = 0.584$, $t = 2.034$, $p < 0.044$; gender $\beta = 3.257$, $t = 6.938$, $p < 0.00$ and weight of kitchen worker $\beta = 0.296$, $t = 21.948$, $p < 0.00$. The variables influencing humidity near stoves in the equation are explained below.

The relationships with air-conditioners and domestic fans indicate that the greater the number of cooling equipment, the lower the heat experienced near stoves. There is strong evidence to conclude that the variables are negatively associated. With p=0.00 and 0.031, respectively; this p-value indicates that the observed difference or more in 0.0 % and 3.1 % of studies would be observed due to random sampling error. Reasonable kitchen air-conditioning design is a balance of spot workstation cooling, occupant ventilation, space pressure relationships, and exhaust replacement air capacity (Clark 2009: 58). Air-conditioners recirculate the air in a room, extract humidity from the air and are an excellent form of dehumidifier (Air Conditioning Industries 2018: 2).

The most common physical symptom of heat in kitchens is heavy sweating with p=.003. Psychological symptoms displayed included use of foul language and since p=.008, strong evidence to conclude that the variables are associated. Use of foul language has a positive relationship with heat near stoves with p=0.008. This p-value indicates that the observed difference or more in 0.8 % of studies could be due to random sampling error. Swearing considered a natural part of most kitchens' lexicon (Spiegel 2016: 1). With cursing being such an accepted part of life in the kitchen, it seems surprising that some restaurants in the UK dismiss employees for swearing. Thermopro (2019: 2) declares that humidity affects sweating. High RH leads to slower evaporation of sweat from the skin and so the body cools down more slowly. Excessive sweating from humidity means that core body temperatures rise resulting in overheating. Heat-related illness (HRI) includes physical symptoms (Figure 2.5) and emotional trauma (Doerr 2019: 3).

Table 8.14 Staff complaints on kitchen humidity

Complaints	Frequency	Percent	Valid Percent	Cumulative Percent
No complaints	17	51.5	51.5	51.5
Sweat not drying	10	30.3	30.3	30.3
Stickiness	4	12.1	12.1	85.3
Uniform is wet	2	6.0	6.0	100.0
Total	33	100.0	100.0	

The variables - staff complaints (Table 8.14) with regard to kitchen humidity and heat near stoves are strongly associated. Alam *et al.* (2019: 4) report that the pantry cars in Indian Railways use several types of cooking equipment, including heaters, ovens, kettles, deep fryers and soup warmers amongst others; these types of equipment produce humid heat during meal preparations. The indoor environment is extremely hot and humid leading to excessive perspiration among kitchen workers. The unfavourable working conditions adversely affect workers’ physical and mental health who frequently suffer from headache and heat stress.

This association for dependent variable humidity near stoves helps to create a strategy to improve kitchen workers' indoor work environment in Durban in respect of heat strain. It has a prediction quality to achieve Objective 2.

8.6 Coping with humidity and heat

All kitchens had cooling devices in addition to extractors to reduce humid heat in kitchens. Section 8.2.1.i and Table 8.15 discuss cooling devices. Kitchen workers and head chefs follow several interventions to cope with humidity. Tables 8.17 and 8.19 indicate that there were significantly more respondents who reported about fewer air-conditioners and industrial fans ($p < 0.05$). A strong correlation was indicated with p=0.040, significant between kitchen worker's perception of ventilation in their kitchen either inadequate or satisfactory and using an air-conditioner in their residence. The cooling behaviour such as the use of an air-conditioner at home after work is likely to help staff to cool off and come to work well-rested previously discussed in section 7.7.

Table 8.15 Cooling devices in the kitchen

Cooling device	Mean	Median	Std. Deviation	Minimum	Maximum	p-value
Air- conditioner	1.45	1.00	0.934	1	4	0.017
Domestic fans	1.55	1.00	0.688	1	3	0.078
Industrial fans	1.92	1.00	1.165	1	4	0.045

Head chefs and kitchen managers claim to have the extractors cleaned (44 %) to reduce humidity in kitchens, whereas 41 % declared that humidity is not a problem in the kitchens (Table 8.16). Almost 30% of kitchen managers open windows and doors and 35.3 % installed fans to cope with humidity.

Table 8.16 Interventions to reduce humidity

Head chef's intervention	Percent
No problem with humidity	41.2
Clean extractor	44.1
Open windows and doors	29.4
Install fan	35.3
Other	17.6

Kitchen workers stand near the air-conditioner or fan; step out of the kitchen, move to the back door where airflow helps cope with stuffiness and heat and or take a short break. The most common behavioural adaptation by workers was to drink cold liquid (94 %). Behavioural modification to cope with humidity includes the use of fans and air-conditioners by kitchen workers (Table 8.17 page 233).

Thirty-five percent (35 %) of head chefs reported that workers took a short break or stepped outside to get respite from the heat (8.8 %). Forty-seven percent (47 %) of head chefs strongly agreed that work experienced played a strong role in coping with heat, followed by race (37.5 %). Fitness and body weight also considered important with 20.6 % and 14.7 % of head chefs, respectively. Other strategies used by kitchen workers included going towards a cooler, sitting in the cooler, putting head inside the chiller, keeping the back door open and pouring water on their heads. Kumar *et al*. (2020: 15) report that students indulge in interactive adaptation such as the opening of windows, doors, fans, changing their activity to rest or take a break from work. Students further drink hot or cold beverage, moving to some airy place or walking indoors or outdoors make themselves comfortable during discomfort conditions.

Table 8.17 Behavioural adaptation to cope with humid heat

Coping strategy	Percent
Drink cold liquid	94.1
Step outside	8.8
Take a short break	35.3
Sit under a fan	14.7
Other	17.6

Moreover, the indoor humidity in the range of 32 % to 67 % and 47 % to 82 % was acceptable to the students (even at high BMR) during autumn and winter season, respectively. Indraganti *et al*. (2015: 292) report that office workers adapt to summer and monsoon (humid) conditions by staying in airy places, drinking cold and or hot beverages and changing their posture. Occupants also avoid direct sunlight, rested, rinsed their face and hands and stayed away from heat sources. It seems drinking hot tea during summer is a cultural practice. Lundgren-Kownacki (2018: 49) reported that buttermilk was widely consumed among workers as a traditional way of mitigating heat strain. Balakrishnan *et al*. (2010: 3) reported fluid and electrolyte supplementation for workers, long rest breaks and sitting under fans. The Heat index by OSHA guides employers on measures to prevent HRI when temperatures are ≥ 39.4 °C and time for serious precautions. Ballman (2012: 1) argues that if the workplace is not dangerously hot, then using fans, drinking lots of water, a cool wet cloth on the forehead from time to time will help cope with heat stress. Several chefs claimed that in Norwich, cool baby wipes are used to wipe heads. Drinking plenty of water helps to get through the heat as a bakery can reach 37.8 °C. About 24 % of staff from the sampled kitchens made cold lemonade to quench their thirst. As per University of Birmingham Health and Safety fact file (2006: 1), there is no specific legislation dealing with humidity. Workers are allowed to take extra breaks, are provided with cold drinks or the dress code could be relaxed. However, health and safety precautions must not be relaxed, even if the temperature is extreme such as wearing the correct protective personal equipment. Education and awareness-raising can also target specific behaviours and practices (WHO 2020). Behaviour modifications include cooking on back burners to increase the removal of cooking emissions and hence always be used first effectively reducing humidity (Singer and Stratton 2014: 23).

8.7 Maintenance of kitchen equipment

Good maintenance standards of clean cooking equipment such as clean ovens, gas stoves and burner ports, grillers and kilns benefit air quality in the kitchens.

8.7.1 Regular upkeep of kitchen equipment

Kitchen equipment such as ovens, stoves and cookers need regular maintenance. It was observed that 31 kitchens had stoves in good repair but only 24 % were maintained clean as was mandatory; 12 % of equipment was only somewhat satisfactory. Just over twenty-nine percent (29.2 %) of the ovens and cookers were clean and 12.5 % of the kitchens had a somewhat, satisfactory report. A minor proportion (5.3 %) of kitchens had equipment-producing soot as grillers and ovens were soiled and scheduled for cleanup. However, almost 58 % of the kitchens had equipment that did not produce soot from burning of spills or unclean equipment. Sixty-eight percent (68 %) of head chefs concur that at most times the equipment is in good repair.

The Meat Industry Guide (2015: 1) claims that food premises and equipment not in good repair and condition are potential sources of contamination of food. Poor maintenance can have health and safety implications for workers. According to NZI Risk Solutions (2016: 5), the key risk for restaurant and cafe kitchens is fire. Deep fryers are typically found in restaurants, QSR, staff canteens and other commercial cooking facilities, when used incorrectly and poorly maintained, they pose a substantial fire risk. A key indicator is the amount of smoke from the oven when opened. The burning of old food and spillages that cause the smoke is not only a fire hazard; smoke particles can be detrimental to health. Therefore, ovens need a good clean, a clean oven extractor is more efficient. The correlation between all kitchen equipment is installed as per specification with all the equipment in good repair, was statistically significant, r (33) = +.519, $p < .002$, two-tailed. These two variables were positively correlated**.** More than 90% of the head chefs stated that all kitchen equipment was installed as per specifications**.**

Appendix 16 indicates that nearly 24 % cleaned extractors once a month, a common feature among franchise food services. However, one kitchen cleaned extractors once a year may be because of light use and low volume cooking. Another two kitchens claimed that cleaning was weekly due to heavy use. Only 15 % of the kitchens had HVAC cleaned quarterly whilst 51 % of the kitchens had HVAC cleaned biannually. Proprietors of commercial kitchens have a duty to ensure that the ventilation system serving the respective premises maintained and operated effectively. According to the SABS Code: 1850 of 2012, commercial kitchens are required to degrease extraction systems, 6 monthly including canopy, extractor filter and ducts (Hygiene and Bugs 2018: 1). For larger institutions, it may be necessary to clean every 3 months. This cleaning procedure ensures the longevity of extractors and keeps the kitchen clean, odourless and free of smoke. This echoes with the requirements in the UK as well.

Almost 30 % of head chefs and kitchen managers agreed that the electrical and mechanical equipment that malfunction, it was serviced within 24 hours; 73.5 % reported that all electrical and mechanical equipment serviced once a week. A minority of respondents (8.8 %) complained that equipment was serviced only when there was a malfunction/breakdown. Food service workers believed that maintenance of lighting was adequate.

The correlation between adjusting oscillating fans and clean oscillating fans was statistically significant $r[13] = +.698$, $p = .008$, two-tailed. Kitchen workers have access to clean fans. High temperatures and humidity can affect the health and comfort of kitchen workers and the use of fans will increase airflow and sweat evaporation. At points of high heat production, use spot cooling fans, evaporative cooling, air-conditioning, general ventilation and local exhaust ventilation.

A kitchen exhaust fan removes grease, smoke, steam and odours while cooking. Grease Cycle (2018: 1) states that grease and debris build up in the filter and slowly start to decrease the effectiveness of extractor fans. With delayed cleanings, a clogged grease filter can become a dangerous fire hazard. Wu’s *et al.* (2019: 1) investigation revealed that the street foodcart workers had high exposure to pollutants due to lack of effective exhaust systems.

A properly prepared equipment specification will define the performance requirements of the equipment, materials of construction, fabrication methods and procedures, test and inspection requirements. Proper definition of these items will ensure that the equipment supplied will meet the performance requirements (Colt Engineering 2006: 1). The correlation between all the kitchen equipment is in good repair and work experience was statistically significant, $r(33) = +.591$, $p < .001$, two-tailed. Thirty-eight percent (38 %) of kitchen managers strongly agreed that all the kitchen equipment was in good repair. About sixty-eight percent (67.6 %) of head chefs agreed that all the kitchen equipment was in good repair most of the time. Moreover, 89 % of the workers felt that the kitchen equipment was in good repair. Respondents also stated that 76% of the gas stoves and 70.6 % of the ovens were in good repair.

8.7.2 Improper maintenance cause unpleasant odour

Good maintenance is a prerequisite for ensuring that a system complies with best practice under statutory nuisance provision. It forms a key element of any scheme designed to minimise harm to the amenity under planning regulations (Croydon Council 2015: 8). In this regard, good maintenance required by the food hygiene regulations to minimise harm and the risk of fire. Canopy and extraction cleaning carried out to the standards and specification of the Heating and Ventilation Contractors Association (HVCA) Standard TR19 in the USA. The recommended cleaning period for extract ductwork according to Thomasnet (2012: 1) is:

- Heavy Use 12-16 Hours per Day 3 Monthly
- Moderate Use 6-12 Hours per Day 6 Monthly
- Light Use 2-6 Hours per Day Once Annually

Accordingly, classified the sampled kitchen as Heavy Use (7), Moderate Use (19) and Light Use (7). Section 7.5.1 and 8.4.3 indicate that fuel and volume of cooking affect the frequency of cleaning of extractors.

8.8 Conclusion

This chapter indicates that reduced airflow accompanied by elevated temperatures and higher humidity levels is causing thermal discomfort. Use of NV induced by cross ventilation between building fenestration supplemented by MV is endorsed in this study for the well-being of workers. Induction heating and electric equipment has lower emissions and lower cooking temperatures when compared to other equipment. Monitoring of cooking oil will help to reduce emissions in kitchens. PPS for high heat producing equipment will comfort kitchen workers. Higher ventilation rates will reduce humidity and discomfort in the kitchen. The next chapter will discuss data analysis of the next parameter of kitchen ergonomics namely, noise.

CHAPTER NINE

DATA PRESENTATION, ANALYSIS AND DISCUSSION: NOISE IN KITCHENS

9.1 Introduction

The previous chapter deliberated the results obtained from the data analysis of parameter ventilation and humidity from this exploratory study. This chapter presents an analysis of data on noise in kitchens obtained from the interview schedule, questionnaires and observation checklist. Noise is a significant component of environmental criteria for well-being in the kitchen (Sanjog *et al.* 2013: 508) and its measurement is essential in composing criteria suitable for work environments (Akbari *et al.* 2013: 1). Earlier research has shown that there is an increased risk of negative physiological and psychological health outcomes with exposure to environmental noise (Christie and Bell-Booth 2004: 1). Data from the primary areas for presentation in this chapter is noise from kitchen activities, equipment and extractors and kitchen maintenance.

9.2 Source and type of noise

The combined noise generated from individual appliances contributes to the total noise in a commercial kitchen (Hima Bindu and Reddy 2013: 1321). Chen and Kang (2017: 6) add that background noise in kitchens emanate from food preparation, mechanical noise of kitchen ventilators, the sound of tossing pans and the sudden sound of breaking dishes. Receiving areas generate higher noise levels caused by delivery personal and trolleys and the ringing of orders (Matyszczyk 2018: 1) created intermittent noise. The widespread exposure to noise in kitchens is of major concern as it affects the well-being of kitchen personnel (Lao *et al*. 2013: 4).

The researcher estimated that the drone of extractors was continuous noise (100 %) whereas the cooking equipment noises were continuous, intermittent and fluctuating (Figure 9.1). Whistling of equipment such as boilers and pressure cookers was fluctuating noise (10 %) whereas the noise from blenders, grinders, ice crushers and potato peelers was intermittent. Staff tend to talk over the kitchen noise and add to the clamour including head chef, kitchen manager, owner, kitchen workers, suppliers, takeaway delivery boys and visitors. Other activities included vacuum cleaning, polishing floors, moving equipment, swinging doors, stacking stock, and repairs in the kitchen and the ringing of telephones and radios. The highest intermittent noise was from staff talking (35 %) as South African indigenous groups tend to talk in higher tones and laugh loudly, sometimes with kitchen workers screaming amongst themselves. Shouting is considered as talking in African culture (Nomad 2017: 1). Williams (2017: 2) explains, "Why Black People are Loud", a historical fact of Africans being slaves. Black South Africans (particularly females) naturally tend to speak at a louder volume than those from the English-speaking West. It is also normal for black South Africans to continue conversations by shouting when situated at a distance from one another (Cultural Atlas 2021: 2). Moreover, the nature of some sounds in African languages which, mindful of their quality, pitch and the strength required in producing them, can be considered loud. This is especially so, given the tonal nature of these languages (Ebrary.net 2020: 1). Section 4.3 reviewed the influence of each of these noise types.

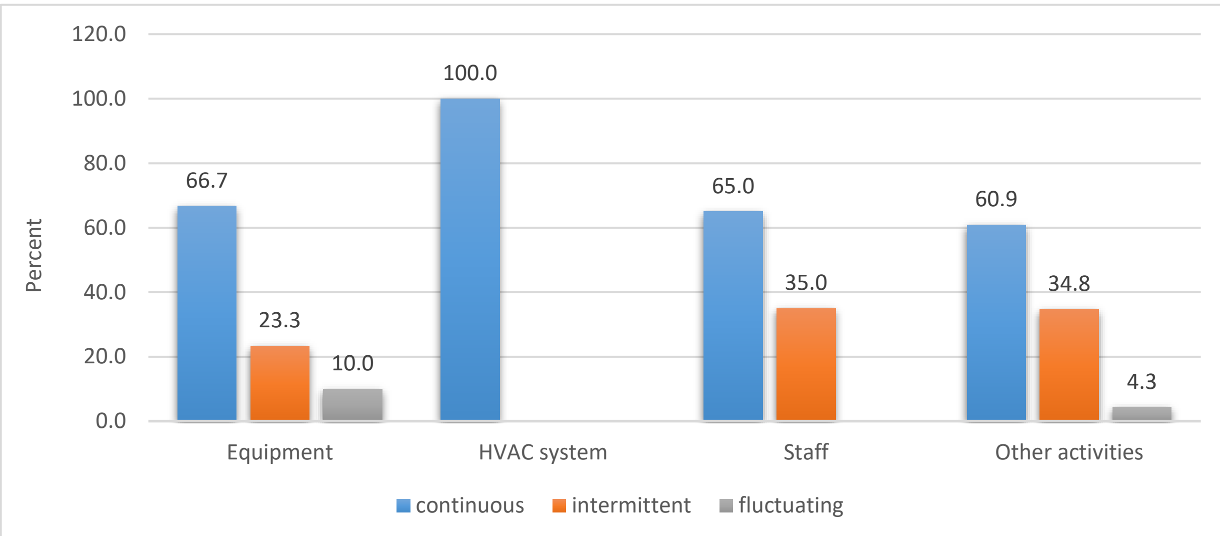


Figure 9.1 Types of noise in kitchens

9.2.1 Noise levels in kitchens

Noise from equipment generated due to food production activities adds to the noise in the kitchen. The preparation area in three kitchens had high noise levels >80 dBA due to potato peelers and salad dryer. The ringing of orders recorded 82.5 dBA in the holding area. The mean values in different areas of kitchens ranged from 43.2dBA to 76.35 dBA (Table 9.1). Achutan (2009: 145), Lao *et al.* (2013: 4), Gladieux (2015: 17), Green and Anthony (2015: 2) all measure values much higher than the current study. Hodgson *et al.* (2009: 39) find that the cooks exposed to daily noise exposures ranging from 72.4 dBA to 80.7 dBA in Canada.

A comparison among relevant studies as mentioned above reveals that high noise levels in kitchens be an occupational hazard to workers. Adverse effects of noise pollution on human health are irritation and annoyance, sleep disturbances, cardiovascular disease, risk of stroke, diabetes, hypertension and loss of hearing which results in decreased work performance (Singh 2018: 37). The higher noise levels recorded in the dishwashing areas concurs with that of Green (2014: 43), whereas Lao *et al.* (2013: 5) had higher levels in cooking areas.

Table 9.1 Mean noise levels (dBA) in kitchens

Areas	Mean	Median	N	Std. Deviation	Minimum	Maximum	Range
Receiving	70.84	68.00	31	17.79	59.00	124.50	85.50
Preparation	71.47	71.00	32	8.59	59.00	96.00	37.00
Stove	75.53	76.00	29	4.79	64.00	85.50	21.50
Oven	73.00	72.20	29	4.16	65.00	80.00	15.00
Holding	71.53	71.00	33	3.88	64.00	80.80	16.80
Dishwashing	75.96	78.00	32	5.38	65.00	83.30	18.30
Corridor	67.24	67.00	31	4.48	50.60	75.40	24.80
Outside	63.20	63.25	30	4.44	55.00	79.00	24.00

Per SANS 10103 (2008: 12-13), 55 dBA is the recommended maximum equivalent continuous rating level for ambient noise in kitchens, dissimilar to the higher noise levels the review of empirical literature. Kerns *et al*. (2018: 485) add that there is a clear relationship between self-reported occupational noise exposure and hearing difficulty. This implies that workers exposed to higher noise levels and suffer hearing loss. The researcher contends that such conditions could also apply to kitchen workers. According to Department for Environment Food and Rural Affairs Finland (2005: 21), different categories of noise in commercial kitchens occur as most cooking devices produce some noise and is especially significant when utilised together.

9.2.2 Cooking activity noises

Even before recognition by OSHA of an occupational noise standard in 1974 as per U.S. Department of Health and Human Services (1998: 17), Williams (1973: 1) established that noise levels in high-volume feeding operations were high. The author reported a background noise sound pressure level (SPL) 90 dBA over the damage risk. In some cases, cooks may also be exposed to 85 dBA noise levels. The noise levels for most restaurants in Morogoro are higher when compared with the Tanzania Bureau of Standards maximum permissible level of 55 dBA. In contrast, the kitchen workers are safe according to the WHO occupational standards whose noise limit value is 85 dBA (Samagwa *et al*. 2009: 32).

A worker can be exposed to noise levels of 99 dBA for 2.5 hours per the Walsh-Healey Act (US Legal 2019: 1) and the Noise Control Safety Orders for the State of California (Department of Industrial Relations 2019: 1) without risking hearing loss. The collective activities in food preparation and cooking areas were observed in the current study to produce excessive noise levels. The mean noise level in the preparation areas was 71.47 dBA (Table 9.1). The mean noise levels from stoves in cooking areas ranged from 53.20 dBA to 75.26 dBA. Fryers and grillers recorded mean noise levels of 68.19 dbA and 53.20 dbA respectively. As kitchen noise stems from kitchen appliances and oral communications between the cooks (Rusnock and Bush 2012: 109), comparisons would assist the exploration of this variable. However, a lack of literature on noise in kitchen areas prevents the researcher's from making such comparisons.

Table 9.2 Kitchen noise levels (dBA) and cuisines

Kitchen areas	**Fusion**	**Continental**	**Contemporary**	**Fast-food**	**Oriental**	**Indian**	**Italian**
Receiving	69.14	69.55	67.13	67.01	62	66.96	66.96
Prep area	72.7	68.5	70.35	70.71	65	**74.85**	70.35
Stove	72.16	74.85	71	73	**84.75**	60.95	60.95
Oven/pizza/tandoor	71	64	70	**80**	0	69.63	47.43
Holding	67.94	73.45	**75.26**	70.28	65	70.38	70.38
Dishwashing	79.94	**81.55**	76.1	78	76.2	78.35	78.35
Corridor	65	55.3	68.38	**70.91**	70.3	65.97	65.97
Fryer	**75**	60.5	71.6	69.4	62.65	63.5	61
Griller	**78**	71.5	71.05	70	0	0	0

From Table 9.2 it can be deduced that the noise levels in the receiving areas are similar in all types of cuisine as it is determined by the supplier communication as well. The Indian cuisine kitchens have louder noise levels in preparation areas due to the style of cooking as indicated in Table 9.3 below. Wok cooking in Chinese/Thai cooking causes noise levels higher than 84.00 dBA. Yu and Wong (2002: 1) reported that the noise levels in a Chinese cuisine restaurant were highest in kitchens with mean noise levels at 87 dBA. The ovens in the fast-food restaurants and corridor areas are much higher due to a larger volume of takeaways. The fryer and griller were noisier in Fusion cuisine kitchens, lower than dishwashing noise of 81.55 dBA in continental kitchens. Yu and Wong (2002: 1) reported that the noise levels in the dishwashing area in a Chinese cuisine kitchen (mean = 82.5 dBA) was higher than the service area (mean = 75.9 dBA). The authors also estimated that 47 % of Chinese restaurant employees were exposed at 85 dBA (daily noise exposure level) as stipulated as maximum permissible levels in the Hong Kong Noise at Work Regulation.

As per Simone *et al.* (2013: 1002), the food service establishment classified as casual restaurants, institutional restaurants or quick-service restaurants requires different kitchen activities such as preparation, cooking and dishwashing. Hence, the noise levels can be higher in fast-food restaurants due to pinging. Preparation and holding areas have higher noise levels from ringing/beep and serving customers (Table 9.2). Reddit (2014: 1) expresses that in quick-service restaurants, aside from the ringing of orders, the fryers and the grills also beep when the food is done. The warming trays have timers set to the number of minutes that the quality of food stays good. The kitchen workers in fast-food restaurants justify the beep noise to be loud and although annoying, it is necessary for drawing the attention of staff.

Casual kitchens have higher dishwashing noise due to manual dishwashing (Appendix 17). Comparatively quick-service restaurants have lower levels of dishwashing due to the use of disposables. Gallego-Schmid *et al*. (2019: 417) observe that there is an increase in consumption of takeaway food in single-use containers worldwide.

More than 58 % of institutional kitchens have dishwashing facility reducing clanging of dishes, although dishwashing machines also add to the noise in kitchens. Almost 43 % of quick-service restaurants and 15 % of casual restaurant kitchens had dishwashing machines. Casual restaurants had higher noise levels of 76 dBA, lower than Green and Anthony (2015: 2) with levels of 105 dBA in locally owned casual restaurants. Hear-it (2019: 1) reports that noise levels vary from 67 dBA to 80 dBA in school cafeteria kitchens. Cisca (2015: 3) observes that open-plan kitchens in casual, quick-service restaurants and fine dining kitchens do not contain noise levels.

The empirical data illustrates that the HVAC extractor system in almost all kitchens produces a continuous noise that drowns other noises in the kitchen (Figure 9.1). It seemed that most staff have become acclimatised to the resultant hum and tend to talk louder to be heard over this noise. Consistent with their cultural practice, a larger number of staff members are loud talkers (Venter 2015: 1). Most kitchens released more noise during the service period when customers were present. The sampled kitchens with authentic Indian cuisine had maximum noise during preparation time attributable to pressure-cooking and grinding spices.

Table 9.3 Noise levels in authentic Indian kitchens

Kitchen area	Noise levels (dBA)
Preparation area	65-96
HVAC	73-83.5
Stove	80
Fryer	80
Pressure cooker whistling	81

Table 9.3 specifically conveys that the highest noise level in preparation areas was from a crusher making a puree of tomato and onion. The noise is intermittent, with high and low peaks. With regard to HVAC, an extractor was loud due to the sound reflected from a metal roof. Pressure gas stoves add to the din followed by crackling noise from the frying of food. It seems whistling from pressure cooking of lentils is a common feature of Indian cuisine.

9.2.3 Noise from equipment

Further to those sources indicated in Table 9.3, other sources of audible noise included intermittent noise from blenders, peelers, and continuous noise from dishwashing machines and ventilation systems. The Fourth European Working Conditions Survey (2008: 120) report that while alluding to the noisiness of small kitchen equipment such as clashing dishes, glasses, cutlery and different kitchen appliances to include grinders and coffee machines, significant noise levels were generated by staff shouting orders and ventilation equipment. Spessert and Vais (2007: 443) find that cooking range hoods and small kitchen devices like blenders, grinders, espresso machines and water kettles are often noisy. These machines disturb communication in the kitchen sometimes severely. It is clear that the greater the preparation involved in cooking a particular cuisine, the higher the noise levels emitted with the use of equipment. According to Erickson and Newman (2017: 452), intermittent noises are likely to cause greater distraction.

9.2.3.1 Effect of noise from stoves

To elicit information on consequences of noisiness, the researcher set out to determine whether worker age, gender and race influence reactions to noise emitted from stoves. The effect of partial eta squared summarised in Table 9.4 is interpreted using the guidelines from Draper (2019: 1) namely, 0.02 - small effect, 0.06 - medium effect and 0.12 - large effect.

Table 9.4 Factors affected by noise from stoves

Tests of Between-Subjects Effects						
Dependent Variable:						
Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Q32.1	14.180	1	14.180	0.830	0.371	0.033
Q32.2	38.446	1	38.446	2.252	0.147	0.086
Q32.3	3.101	1	3.101	0.182	0.674	0.008

The results in Table 9.4 indicate that whilst reaction to stove noise (DA92.3) is affected mildly by age of the worker (Q32.1), and race (Q32.3) a moderate effect is observed by gender (Q32.2) of the kitchen worker. The reactions to stove noise seem to vary widely between males and females. The relationship of specific items in 4.7 and finding in 9.2.4.1 is beyond the scope of this research and cannot elaborate on these relationships due to lack of sufficient data; the current research is not a longitudinal study. Although age is associated with hearing loss, genetics and gender has also been linked to hearing loss from noise (Daniel 2007: 229). The difference between medium and large effects seems to be great. A survey by Lao *et al.* (2013: 7) illustrates that pressurised gas stoves are the major source of noise in the kitchens of Chinese restaurants in Hong Kong. Casey's *et al*. (2017: 7) survey reveals that levels of noise are higher in dwellings among Blacks compared to Whites, however, Lin *et al*. (2011: 109) report that the odds of hearing loss are substantially lower in Black than in White individuals.

Table 9.5 Component Matrix for noise from cooking equipment

Cooking Equipment	1 Noise Index
Ovens	0.761
Boilers and steamers	0.883
Gas stoves	0.897
Fryers	0.761
Extraction Method: Principal Component Analysis.	
a. 1 components extracted.	

The sampled kitchens emitted noise levels ranging from 64.00 to 85.50 dBA, with higher values from gas stoves and lower values from electric stoves. This implies that food service workers may suffer from NIHL as the permissible noise exposure level according to WHO is 80 dBA (Fligor *et al*. 2014: 1535).

Using exploratory factor analysis, item 34.1 in the questionnaire revealed a factor loading of 0.761; 0.883; 0.897 and 0.761 for ovens, boilers and steamer, gas stoves and fryers respectively and was categorised into component 1, Noise index. This kitchen equipment ranked according to the mean level noise produced during food production. These variables load perfectly into a single component. A longitudinal study will elicit the effects of the noise measured in kitchens. The association of the high loadings of ovens, broilers, steamers, gas stoves and fryers could imply that the kitchen workers are constantly exposed to high noise levels.

The convection oven fans produced noise levels of 72 dBA much higher than other electric brands. Elliott (2019: 1) reports that different noise levels observed, KitchenAid ovens have noise levels of

55 dBA to 60 dBA, AGA ovens clock 60 dBA to 65 dBA; Wolf ovens measured 50 dBA to 55 dBA. According to Samsung (2020: 1), the convection fan at the back of the oven circulates heated air for more thorough cooking. The convection fan turns on and off at regular intervals and has a quiet, low humming noise. If the oven is being excessively noisy, there is likely to be a problem with the fan motors; the bearings can wear out, causing a rattling sound when the oven is on (Gilbert 2015: 3). The association of these facts on food service workers implies that they are persistently exposed to noise.

A chi-square test of independence was performed to examine the relationship between different cooking equipment noise and their rankings in terms of maximum noise. Since the p-value is larger than the significance level of 0.05, there is not enough evidence to conclude that the variables are associated.

Table 9.6 Chi-square between stoves and noise in kitchens

Cooking Equipment	Chi-Square	Df	Asymp. Sig.	Exact Sig.	Point probability
Ovens N=29	5	5	0.416	0.474	0.00
Boilers and steamers N=20	3.4	5	0.639	0.701	0.099
Gas stoves N=29	6.421	6	0.378	0.420	0.079
Fryers N=29	14.69	6	0.023	0.023	0.003

The Chi-square test as indicated in Table 9.6 test how likely it is that the observed distribution is due to chance. Called a "goodness of fit" statistic, it measures how well the observed distribution of data fits with the distribution that is expected if the variables are independent with significance levels equal to any value between 0 and 1.

The different cooking equipment produces diverse noise levels and does not influence each other. The number and size of equipment were wide-ranging and the frequency of use was diverse in preparing different cuisines. Hence, it seems variations in noise levels are expected. The variable differences in noise levels from cooking equipment helps to customise noise reduction plans in different kitchens zones to compose indoor environmental criteria for design of restaurant kitchens in Durban with respect to noise. It has a prediction quality to achieve Objective 1.

9.2.3.2 Noise levels from dishwashers

Whereas the noise within dishwashing areas in the current study was highest with a mean level of 76.35 dBA, it was much lower than the 82.5 dBA in Lao *et al.* (2013: 4) as well as Achutan (2009: 145) where mean range values between 72 dBA to 81 dBA. Williams (1973: 1) was early in detecting all pot and dish machine operations had background noise levels averaging 82 dBA, and impact noise was highest and frequent in terms of occurrence. Green and Anthony (2015: 2) claim that dishwashers are the most highly exposed workers, so customising noise reduction plans to different job requirements is necessary. It noted that the items loaded perfectly along a single component. Using exploratory factor analysis, items revealed a factor loading of 0.877 and 0.877 for dishwashing machine producing noise and heat respectively and was categorised into component 1, Discomfort Factor.

Table 9.7 Component Matrix for Dishwashers

Dishwashing machine - noise and heat	Component 1 Discomfort Factor
Dishwashing machine- noise	0.877
Dishwashing machine producing heat	0.877
Extraction Method: Principal Component Analysis.	
a. 1 components extracted.	

Only 36.4 % of the kitchens had dishwashing machines and 33.3 % of kitchen personnel were dissatisfied with the heat and noise from dishwashers. It seems noise from dishwashing machines can add to the din in the kitchen and distort hearing ability. When sounds travelling from different directions reach a worker who cannot determine the source, it will result in disruption (Resonics 2018: 1). The super-imposition of the direct and indirect sounds creates an increase in sound level, which may distort audibility (Olatubosun *et al.* 2007: 8). Hence, this area of the kitchen constitutes a significant parameter for its contribution to kitchen noise discomfort. Figure 9.2 illustrates the observation of noise generated from dishwashing machines during the washing cycle.

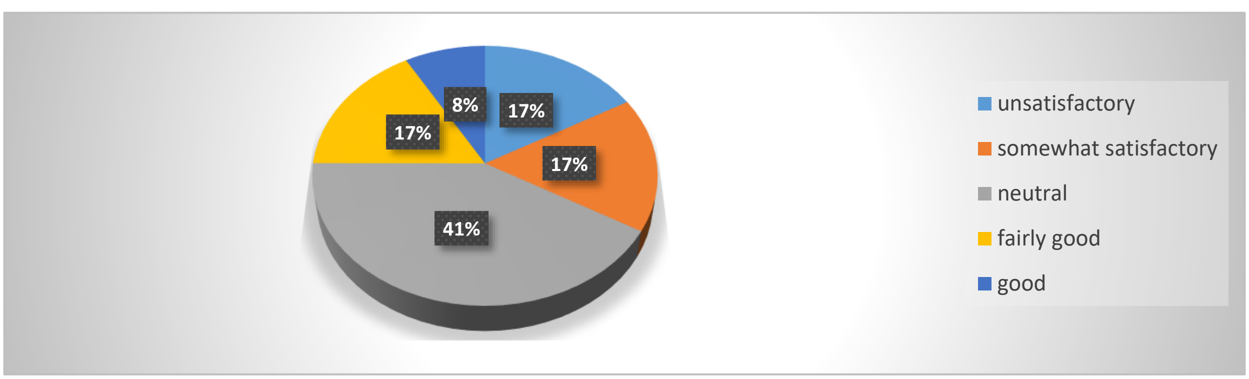


Figure 9.2 Researcher's opinion on dishwasher noise

More than 66 % of the dishwashing machines were inside the noise comfort range of 70 dBA as asserted by Fox (2019: 1) although, Goldsmith (2013: 6) only allocates a low noise level of 50 dBA for a domestic dishwasher. The noise of the wash cycle was perceptible in 17 % of the sampled kitchens. The noise levels ranged from 65 dBA to 79.8 dBA. Gladieux (2015: 17) cautions that employees using commercial dishwasher machinery are at risk for overexposure to noise, with 31 % of the full shift noise levels to be above the Occupational Safety and Health Administration (OSHA) Action Limit of 85 dBA as per National Institute for Occupational Safety and Health (NIOSH 2007). More consistent with the present work is that of Green and Anthony (2015: 12) who found that the mean exposure for the data set was 80 dBA; no workers were exposed to noise above the OSHA permissible exposure limit of 90 dBA, but dishwashers are exposed to noise levels >85 dBA in high-volume restaurants. The researcher observes that kitchen equipment and machinery like dishwashers vibrate and contribute to structure borne noise.

9.2.3.3 Extractor system noise

The noise from extractor systems varied from 70 dBA to 83 dBA. Specifically, the item in the questionnaire indicated in the rotated matrix component is 'staff complained about extractor making too much noise'. Goldsmith (2013: 6) allocates a low noise level of 65 dBA for an average cooker hood, although Fox (2019: 1) makes a 70 dBA determination. Variation in the observed sizes of the kitchen exhaust along with the flow rate of air and type of fan according to Gladieux (2015: 17) influence the level and nature of noise emitted.

9.2.4 Grading and rating of equipment noise

Equipment noise levels subjectively ranked by head chefs and kitchen managers in Figure 9.3 indicates ranking by percentage. Whereas old air-conditioners in a kitchen produced noise, environmental systems air-conditioners in other kitchens demonstrated low mean noise emission. Fox (2019: 1) accounts for noise levels of 60 dBA for air-conditioner whereas Garg and Maji (2016: 35) report 72 dBA from air-conditioners whether split or indoor; 55 dBA is the maximum permitted sound power for refrigerators. Fox (2019: 1) however, claims 50 dBA for refrigerators and yet, Goldsmith (2013: 6) asserts 40 dBA is ideal. These recommended noise levels are much lower than the observations in the sampled kitchens.

Refrigerators in the sampled kitchens had noise levels ranging from 64.5 dBA to 75 dBA, while 73 dBA was the mean noise level for freezers. The noise from grinders and blenders despite its loudness was mitigated by non-continuous usage and their usage for short periods. Fans in convection ovens made noise upon switching to air circulation. André *et al*. (2020: 990) verified that the noise produced by the fan was a barrier to increasing air movement. The absence of literature on kitchen equipment rating makes it challenging to draw comparisons to help identify an ideal. The grading of equipment noise indicates that the equipment needs maintenance for reduced noise production. The researcher nonetheless surmises, that as the frequency and the wear and tear on equipment varies widely across kitchens, noise from the similar equipment varied between kitchens.

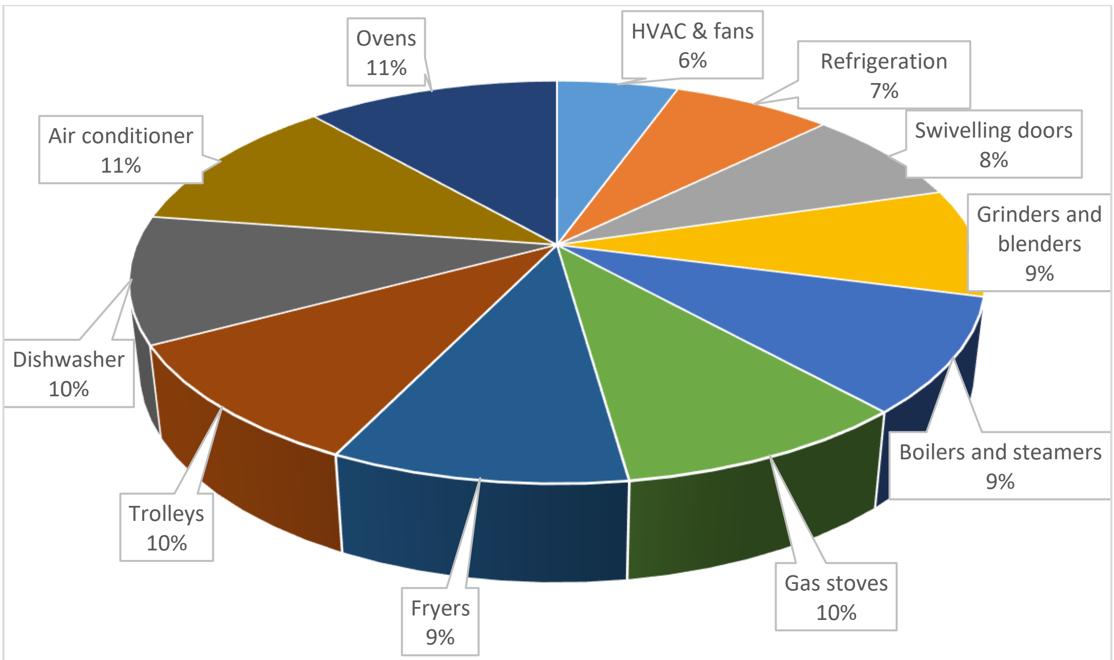


Figure 9.3 Common fitment and equipment noise rating

There is a need for a model that accounts for the variables that may affect noise ratings. A new monitoring concept in which an acoustic pattern classification algorithm running in a wireless sensor can be used to automatically assign the measured sound level to different noise sources (Maijala *et al.* 2018: 258).

Appendix 18 indicates weighted mean from most to least noisy; 10 % of the head chefs subjectively ranked gas stoves, boilers and steamers (10 %) as the notable source of noise in kitchens followed by ovens (6.3%) and fryers (3.4 %). It was noticeable that in 51 % of kitchens the noise from extractors was > 40 dBA although all the head chefs claimed that extractors were fitted with fan silencers.

Alexandrova (2009: 8) suggests the reduction of ventilation speed when the cooking process has stopped; when extractor fan speed reduced by 80 %, a 20% reduction in noise will occur. A chi-square test indicated that the variables are associated. Wong *et al*. (2011: 748) reported that the mean noise level of 88.8 dBA in gas kitchens was 9 dBA higher than in kitchens using electricity, implying an almost eightfold increase in sound intensity. This section will accordingly account for the findings of the effect of noise on kitchen personnel and elaborate on the variation with current outcomes and the implication on managing kitchen noise.

9.3 Effect of noise exposure

Kitchen workers are especially exposed to high noise levels in catering (Carayanni *et al.* 2011: 200). The work of Wong *et al.* (2011: 747) bear testimony to the noise in kitchens, which is primarily due to the noise generated by cooking activities.

9.3.1 Workers are vulnerable to noise exposure

Whilst workers are vulnerable to noise exposure, they accept it as part of their occupational risk. Nonetheless, over 45 % of the staff felt that noise was not a problem in their kitchen. This reflects their resistance to noise levels and not vulnerability. The interviews revealed that 11.5 % of the workers thought it was a problem and they could be prone to hearing loss. Similar results were obtained internationally. Hima Bindu and Reddy (2013: 1021) found that when cooks are exposed to high noise levels during peak hours they reported that at times they found it difficult to concentrate due to prolonged exposure to noise. Samagwa *et al.* (2009: 32) caution that the lack of awareness of noise pollution by 45 % of interviewees hold negative implications for the auditory health of the kitchen workers. In the same vein, the Fourth European working conditions survey report in European Agency for Safety and Health at Work (2008b: 120) finds that of the 29 % of workers in the sector exposed to noise just over 4 % consider that they are at risk of developing hearing problems such as noise-induced hearing loss (NIHL).

Lao *et al.* (2013: 9) confirms that kitchen workers suffer from NIHL. Gardner *et al*. (2014:193) declare that employees in hospitality are at moderate risk of NIHL with median daily sound exposure of 74 dBA. Even though subjective noise was higher, attitudes towards noise control were not positive among hospitality staff. The author adds that hearing protection devices (HPD) are not used in customer service environments and hence, suggests that a focus on control of noise is required, as noise hazards are underestimated due to the insidious nature of NIHL. It is accordingly likely that kitchen workers in the current study may suffer from NIHL over a period of years. In South Africa however, there is currently no universally accepted general standard for parameters of the earliest changes of NIHL (Bomela 2006: 24). Green and Anthony (2015: 11) report that the range of food service worker exposures to noise may be dissimilar in different geographical regions.

9.3.2 Workers' opinion on noise levels in kitchen

The workers' opinion on sound levels in kitchen is associated with the effect of noise exposure. The sampled kitchen workers speak louder over the din, but confident that noise-induced hearing loss does not occur in their kitchens. Nonetheless, a small proportion of kitchen workers (11.5%) respond that the noise levels at their workplace may affect their hearing, previously, only 3% of people were aware of it. While there is no empirical work on kitchen worker opinion on sound levels in kitchen, Kanji *et al*. (2019: 305) report that the majority of South African mine workers demonstrate knowledge of the consequences of noise exposure on their hearing function. Age as discussed in section 9.2.4 is a significant possible cofactor of NIHL. Graydon *et al*. (2019: 23) believes that hearing impairment can have significant consequences for kitchen workers over time with a mean duration of 4.4 years' work tenure in the kitchen. Oseland (2015: 1) asserts that the consequential psychological factors have a greater effect than the sound itself. No significant findings were obtained in the current study on any psychologically related findings from noise in kitchens.

Forty-seven percent (47 %) of the kitchen managers responded that the kitchens had no problems with noise (Figure 9.5). They expect operating kitchens to be unavoidably noisy but tolerable. When the noise became louder, the coping behaviour was to switch off the offending equipment until when needed. Diamond *et al*. (2012: 57**)** recommend a protocol accordingly that includes switching off the cooking equipment and dishwasher immediately after use; and where extraction is manually controlled, the kitchen staff has the responsibility for switching it off.

The kitchen managers' opinion was important, as they are key to effecting measures that generate comfortable noise levels. The subjective response indicates that only 6 % of head chefs believed that with higher noise levels in kitchens, it is not possible to talk to the colleagues without shouting. Practically 85 % of head chefs sensed that kitchen workers complained about stoves and fans making too much noise. The Illinois Department of Employment Security (n.d) reports that chefs sometimes work in a noisy and distracting environment. Chen *et al*. (2018: 10) posit that even if noise in the workplace is not loud enough to cause hearing loss, a poor acoustic environment can contribute to voice strain among workers. Almost 70 % felt that blenders and grinders made noise and workers were unable to communicate with colleagues, although nearly 58 % agreed that staff complained about extractor noise as well. Wei *et al*. (2017: 3228) criticise that noise emission of range hoods is a major concern to manufacture owing to the deterioration in the customers' audible perception and the noise-related customers' complaints. Literature to support the opinions of kitchen managers on noise is unpublished.

The subjective judgement of surveyed staff revealed complaints about blenders, grinders and food processors making too much noise; objective measures found noise found to be closely associated with the preparation area (Appendix 24). Since p=0.009, there is strong evidence to conclude that the variables are associated; the higher noise lead to complaints. Carayanni *et al.* (2011: 200) reported that 41.7 % of kitchen Greek workers complained that noise was high in kitchens. Intermittent noise from blenders was reported by 91 % of kitchen workers in the present study. The possible implications on complaints of the stated variation with the intermittent noise from blenders in the current study include difficulty in communication with other kitchen workers with a possibility of NIHL. According to Erickson and Newman (2017: 452), intermittent noises are likely to cause greater distraction.

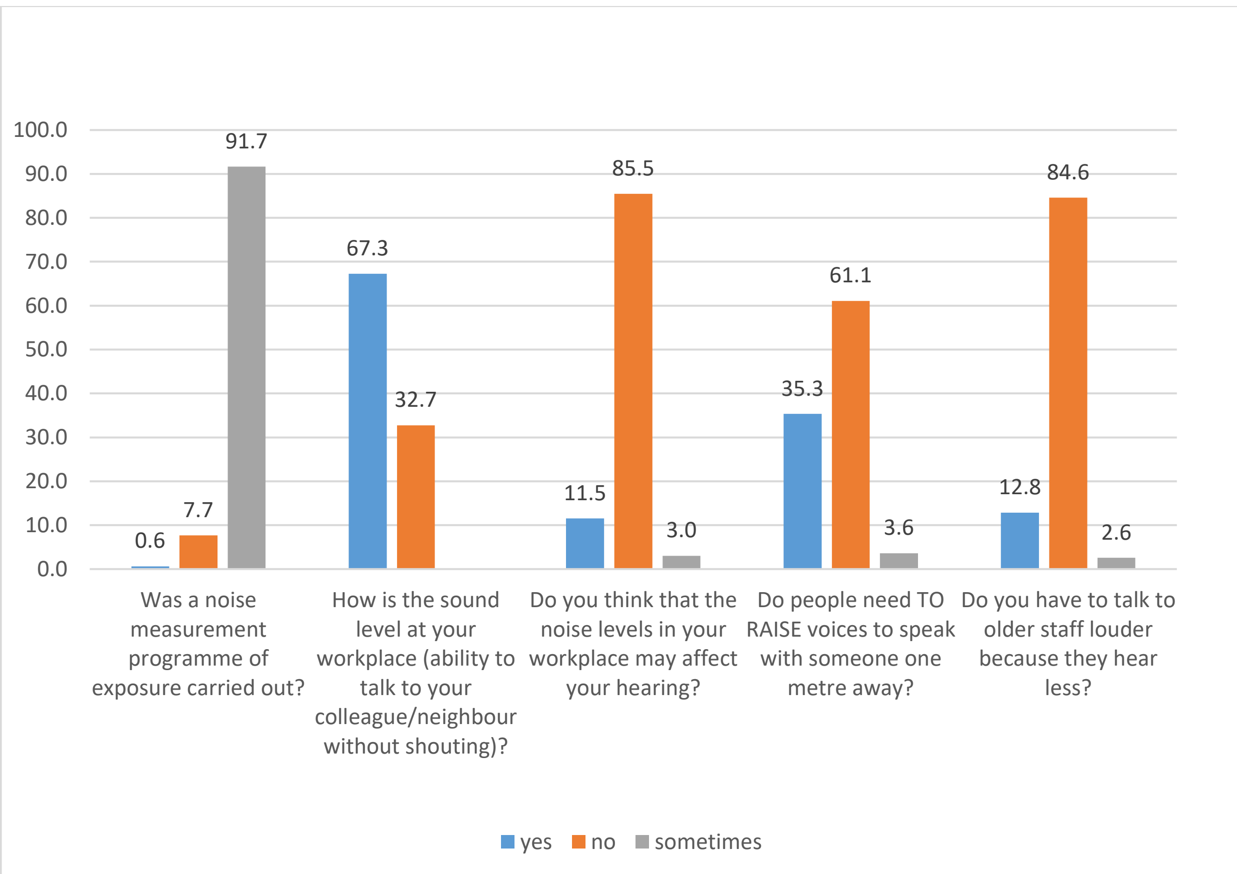


Figure 9.4 Workers' experience of kitchen noise

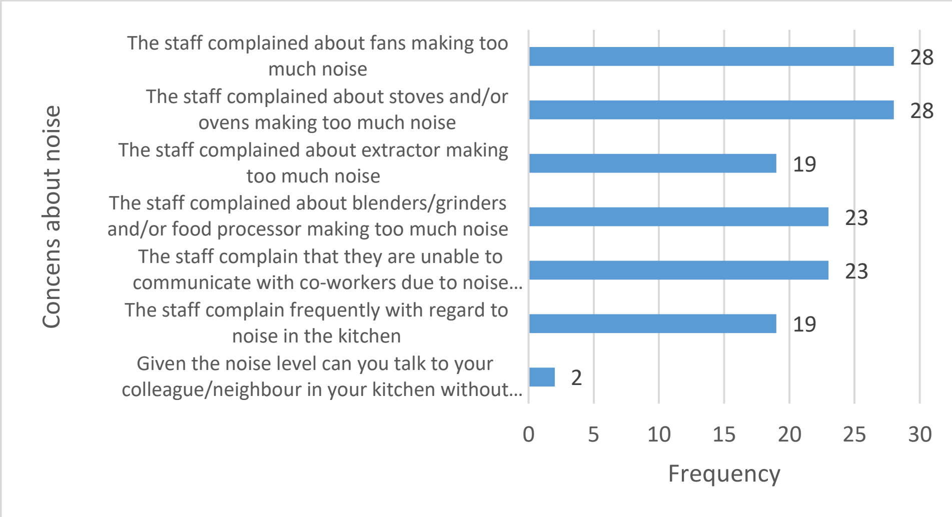


Figure 9.5 Kitchen managers' opinion about noise

Nearly 35.3 % of kitchen workers responded that they have to raise their voice to talk to a colleague one meter away. According to Gorvett (2019: 2), conversations were rated the most disturbing, as workers are better at complex tasks in total silence. Spessert and Vais (2007: 443) find that sometimes small kitchen devices disturb communication in the kitchen significantly. They diminish the concentration of kitchen workers and prevent communication.

Using exploratory factor analysis (Table 9.8), the items 43.6, 43.8 and 43.9 from the Questionnaire revealed a factor loading of 0.621, 0.710 and 0.850 for complaints about noise in kitchen, noise from grinders and noise from extractor respectively and was categorised into component 2, Uneasiness Factor (Table 9.8). The possible repercussions of high factor loading of noise in kitchen, noise from grinders and noise from extractor on worker complaints of equipment noise include inability to communicate with other staff and consequently talk louder to them adding to the din. The questionnaire further revealed that the level of noise from the operating extractors was ≥ 65 dBA in most kitchens while in four kitchens it was a noticably higher 75 dBA due to improper maintenance. These noise levels can be lowered by using rubber mats that reduce heavy vibrations and disturbing sounds (Loewen and Suedfeld 1992: 1) but were not observable although the staff claimed that they placed them under the grinders while in use.

Table 9.8 reveals a factor loading of 0.612, 0.917 and 0.900 for unable to communicate, grinders making too much noise, and noise from fans respectively and was categorised into component 1, Discomfort Element. At a milder level, Garg and Maji (2016: 35) report that noise from electrical fans are in the range of 70 dBA.

Table 9.8 Rotated Component Matrix: noise complaints from kitchen workers

Rotated Component Matrix[a]	1 Discomfort Element	2 Uneasiness Factor	3	4
6. The staff complain frequently with regard to noise in the kitchen	0.360	0.621	-0.320	0.152
7. The staff complain that they are unable to communicate with co-workers due to noise in the kitchen	0.612	0.530	-0.085	0.041
8. The staff complained about blenders/grinders and/or food processor making too much noise	0.328	0.710	-0.007	0.009
9. The staff complained about extractor making too much noise	0.105	0.850	-0.112	0.120
10. The staff complained about stoves and/or ovens making too much noise	0.917	0.236	-0.155	-0.031
11. The staff complained about fans making too much noise	0.900	0.217	-0.255	-0.049
Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.				
a. Rotation converged in 5 iterations.				

André *et al*. (2020: 990) verified that the noise produced by the fan was a barrier to increasing air movement. This can interfere with speech and the ability to communicate (City of Tshwane 2004: 6). Figure 9.4 accordingly illustrates that communication was difficult for at least 32.7 % of the respondents who to be heard had to talk louder to their colleague, and 35.5 % workers had to raise their voices to talk to their colleagues who were just one metre away. The researcher suggests a consequence of poor audibility in kitchens can fill the kitchen with excessive noise, cause delays and errors and ineffective emergency decisions. Further to causing discomfort to kitchen staff, noise could be disturbing to other workers in a food service operation (Urbanclap Homes 2018: 1).

Appendix 24 indicates that staff complained that they are unable to communicate with co-workers due to noise in the kitchen has a p=0.504 and chi-square statistic of 31.29, with significance level of 0.002 with staff complaining frequently with regard to noise in the kitchen. Excessive noise and poor acoustics can affect communication (Resonics 2018: 1).

A busy kitchen in the midst of meal service can be a noisy environment in which it is hard to understand speech. Kitchen workers need to speak more loudly but avoid shouting because shouted words are more difficult to understand (British Columbia Campus 2020: 1). Hima Bindu and Reddy (2013: 1021) report that even essential verbal communication between kitchen colleagues requires effort due to noise in the kitchens, causing irritation and distraction. The benefit of silence is good for the well-being of kitchen staff (Alexandrova 2009: 8). In contrast, the kitchen workers continue to talk loudly even when not required due to their cultural habits as observed by the researcher, yet the interview respondents complained that noise levels are high in the kitchen.

A strong negative correlation (p = -0.894) is seen between noise from air-conditioners and noise from HVAC system with significance level of 0.041. This means that both air-conditioners and HVAC systems need not be noisier in any particular kitchen, making it easier to manage kitchen noise emission. The staff complained about extractor making too much noise correlates with staff complained frequently with regard to noise in the kitchen. Like most machinery, a well-maintained extraction system is far more effective and far less noisy (Cater Clean 24 Seven 2017: 1).

9.3.3 Natural adaptation to noise

The earlier mentioned effect of noise on the kitchen worker been eased by natural and artificial adaptations. For example, people exposed to a noisier environment may not have to cover their ears according to Rivas (2015: 1) because of the brain's natural ability to adapt as the cells in the auditory nerve adjust and change to respond to a different heightened level of activity.

Table 9.9 Managers'opinion on adaptation to noise

Factors	Percent
Age	38.2
Gender	5.9
Race	20.6
Work experience in kitchen	41.2
Work activity	11.8
Other	11.8

However, head chefs and kitchen managers agree per Table 9.9 there are several natural and acclimatisation factors that shape the workers' ability to cope with noise levels in the kitchen. The average age of the kitchen workers was 31.28 years with a standard deviation of 8.56 years (Table 9.10). Head chefs and kitchen managers (38.2 %) contend that age is the chief natural factor in adapting to noise in kitchens (Table 9.9). The findings disclosed that 12.8 % of the kitchen workers believed that they had to talk louder to older staff as they hear less. A further 2.6 % of the respondents talked louder to older staff sometimes. Age is a significant possible cofactor of NIHL as elaborated in section in 4.8.1.

Table 9.10 Age of kitchen staff in the sample

Kitchen staff	N	Minimum	Maximum	Mean	Std. Deviation
Kitchen workers	170	19	62	31.28	8.557
Head chefs/ kitchen managers	33	23	49	34.68	6.545

According to Table 9.10, the mean age of head chefs was 34.68 years with a standard deviation of 6.545. Within the age category of 30 to 39 years, 77.8 % were male. Within the category of males (only), 66.7 % were between the ages of 30 to 39 years. This category of males between the ages of 30 to 39 years formed 41.2 % of the total sample who can adapt to noise.

Almost 6% of the head chefs believed that gender affects adaptation to noise in kitchens. Kitchen workers are predominantly female as discussed in section 4.7.2. Almost 64 % of the food service workers in the sampled kitchens were female. Contrary to Tiller *et al.* (2010: 534) who reported that females were more sensitive to sound, observations by researcher revealed otherwise. This could also be due to the ethnicity factor.

Nearly 21 % of the head chefs assumed that race is an important factor in adaptation to noise. Frontczak and Wargocki (2011: 937) suggest that acoustic comfort is affected by the country of origin. Consistent with the cultural practice in Africa, a larger number of staff members are loud talkers (Venter 2015: 1) and shouting is considered as talking among Africans (Nomad 2017: 1). This could help with adaptation to noise among African workers.

It seems that the role of work experience (41.2 %) is in psychological preparation for expected noise levels. Khalighinejad *et al*. (2019: 1) report on the adaptation of the human cortex to changing background noise that helps with aural adaptation as intrinsic dynamic mechanisms enable a listener to filter out irrelevant sound sources in a changing acoustic scene.

9.4 Kitchen noise reduction strategy

Amongst the numerous specifications for noise management, the Noise Rating (NR) Curve was developed by the International Organization for Standardization (1973) as per Engineering Toolbox (2004: 1). It determines the acceptable indoor environment for hearing preservation, speech communication and annoyance In addition, SANS specifies 55 dBA. However, per earlier mention in 9.2.1, kitchens are unable to contain noise levels recommended within the published minimum standard of SANS.

To control noise at the source, it is necessary to determine the cause of the noise, and how to reduce it (Hansen *et al.* 1995: 250). Such need is amplified in a majority response complaining of noise, further affirming it as a vital parameter for the management of kitchen environmental criteria. Whilst 47 % of respondents did not experience any difficulty with kitchen noise, Figure 9.6 indicates the steps taken by staff to curtail noise.

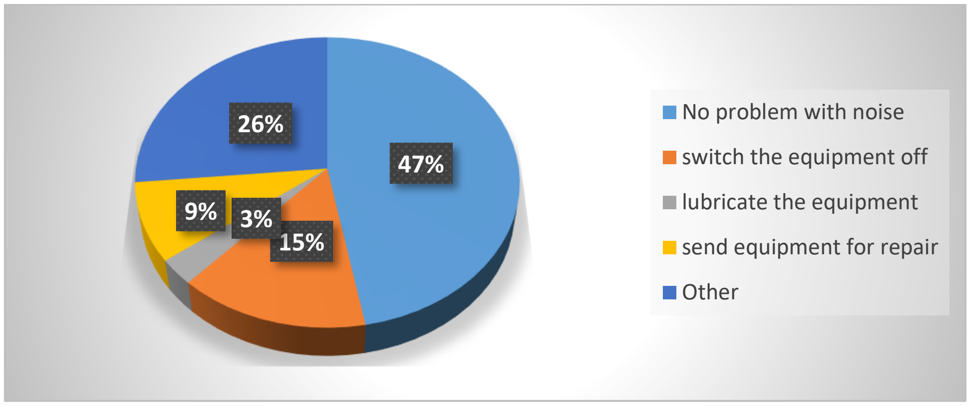


Figure 9.6 Steps taken by staff to curtail kitchen noise

Simple solutions like lubricating the machine reduced noise by 3 % from equipment whereas 9 % sent equipment for repair. Fifteen percent (15 %) switched off the equipment and 26 % placed mats under the blenders and grinders. However, the researcher could not observe any rubber mats installed under blenders and grinders to absorb the noise. It observed that only 12 % of kitchens had rubber mats on the floor, near the sinks in the dishwashing area for nonslip, and absorbing noise generated from the manual dishwashing process. Rubber reduces heavy vibrations and disturbing sounds. The more expansive the kitchen area, the less noise perception by workers. Other strategies comprise of placing kitchen towels or tablemats under the equipment to absorb noise.

The researcher's observation accords with that of Serfoso (2018: 1) where the latter discerns that small steps in facility design and equipment selection can greatly reduce noise levels. For instance, good acoustics can actually mean a 15 % less cognitive stress for workers. Hansen *et al.* (1995: 250) recommend rearrangement and careful planning of buildings and equipment with organisation of production lines so that noisy equipment is separated from workers as much as possible.

9.4.1 Noise and kitchen spaces

The height of the sampled kitchens varied from 2.41 m to 4.17 m. The voluminous space due to higher ceilings per Leider (2015: 1) increase sounds to be even louder and more intrusive. High ceilings create echoes. Resonics (2018: 1) supports the claim that higher ceilings increase volume in a room meaning sound is lost in the 'dead space' above workers heads. They also result in higher reverberation times as sound waves have to travel a long way before they are reflected by a hard surface. Therefore, high ceilings are bad for room acoustics.

9.4.2 Area and volume of the kitchen

The total floor area of kitchens in Figure 8.1 varied from 17.10 m^2 to 248.08 m^2. Benghiat (2019: 2) observes that smaller kitchen are not necessarily better as they tend to exhibit more acoustic issues than larger rooms. Sound waves in small rooms have less time to decay and thus end up creating interference that is more destructive. Very few kitchens had area greater than 200 m^2. Significantly, more respondents (86.7%) indicated that the kitchen area was less than 100 m^2 ($p < 0.001$).

The volume of sampled kitchens varied from 43.58 m^3 to 426.05 m^3 (Table 8.2 page 200). Higher ceilings increase volume in a room and as noise travels; its intensity is lost in the space but results in higher reverberation times before it reflected by a hard surface. Hence, high ceilings are bad for room acoustics (Parkin 2015: 2). Domes and concave surfaces caused the reflections to be focused and absorptive surface treatments can help to eliminate both reverberation and reflection in kitchens. However, the noise findings of worker well-being is attributed to high ceilings. For example, workers who had no problems with noise are mostly from large spacious kitchens (21 %).

9.4.3 Ceiling, floors and walls

It is imperative to prevent sound waves from bouncing back off the kitchen walls and contain the sound in one location. Restaurant kitchens need soundproofing materials to stop noise from entering the dining room (Morrell 2015: 1). Table 9.11 informs that 60.6 % had plasterboards and 6 % of the kitchens had metal ceiling tiles, metal panels are good for sound management in food preparation areas (Acoustical Surfaces Inc. 2020: 7). When selecting metal ceilings, the perforation pattern affects the acoustical absorption of the ceiling (Browne 2019: 1).

Twenty-four percent (24 %) of the kitchens had concrete ceilings. Only one kitchen had a corrugated metal roof. Suspended ceilings absorb more noise than concrete ceiling as hard surfaces reflect sound. Suspended acoustic tile ceilings are not permitted in food preparation areas, or where food is served (Mignanelli 2015: 32). However, 11 % of the kitchens had false ceilings.

Acoustical treatment of ceilings in kitchens is necessary, as the noise seems extremely severe at times due to cacophony during peak periods as experienced by the researcher. An ordinary plaster ceiling can provide adequate sound insulation except in extremely severe cases; however, suspended ceilings are the most effective noise reducers (US Department of Transportation 2017: 4).

Table 9.10 Summary of construction material in kitchens

Construction	Finishes	Percent
Ceiling	Plaster board	60.6
	Concrete	23
	False ceiling-gypsum	11
Floors	Porcelain tiles	78
	Vinyl	9
	Cement	13
Walls	Ceramic tiles	88
	Plaster	6
	Concrete	6

The use of concrete in kitchen construction provides, according to Home Improvements (2017: 1), a good reflection of sound and does not transmit or absorb sound. Painted and plastered concrete is even more reflective and less transmissivity, although concrete floors and walls can prevent sound from carrying over to the next room to some extent. Noise barriers such as block, concrete or brick and metal considered reflective and absorptive treatment can be added.

The current study observed that concrete is commonly used for ceiling and floors. Resonics (2018: 1) advises that a minimum of 1/3 of the space be covered with soundabsorbing materials for optimal results. The acoustic treatments spread out as much as possible to ensure that noise is absorbed from as many directions as possible. A mixture of ceiling and wall panels/acoustic treatments are ideal. Again, this ensures that sound is absorbed from different parts of the room and prevents echo.

Cambridge City Council (2013: 3) regulations for floor surfaces include vinyl, quarry tiles, ceramic tiles, terrazzo tiling and cast resin flooring. Seventy-eight (78 %) of the kitchens had tiled floors and 9 % had epoxy floors (Table 9.11). Mattoon (2019: 2) declares that seamless, epoxy floors can positively influence acoustics without sacrificing durability, function and important in slippery areas and last in even the harshest environments. Commercial kitchen flooring must comply with building code requirements (Lewitin 2018: 1). Staff walking down a painted dense concrete hallway in capped boots will be very noisy, but a customer in a restaurant may not hear the noise very well (Concrete Construction Staff 2001: 1). Poly vinyl chloride (PVC) tiles are suitable safety flooring for wet and greasy conditions. It helps reduce fatigue, provides noise reduction and comfort underfoot (Altro 2018: 1).

According to Table 9.11, more than 88 % of the kitchens had glazed ceramic tiles on walls. Six percent (6 %) had brick walls covered with plaster. One of the best methods to soundproof a wall is to build a wall over the existing one with soundproofing materials. Brick walls block out sound because it is dense (Davidson 2019: 1). Sound waves do not easily penetrate brick walls but is reflected and affect the noise of the room. Cambridge City Council (2013: 3) recommend stainless steel walls or alternatively, washable paint, epoxy resin coating, or ceramic tiles.

Soundproofing in some kitchens appears to be successful. Acoustical Solutions (2019: 1) report that kitchen noise was successfully ameliorated by the installation of acoustic panels strategically along the perimeter walls of the kitchen; with 2″ (5.08 cm) thick acoustic ceiling tiles, echo and reverberation decreased in the kitchen; speech intelligibility increased and patrons seated in the dining hall no longer heard kitchen noise. Acoustic tiles were not observed in any sampled kitchens due to lack of awareness about noise levels in kitchens according to the head chefs and kitchen managers. Restaurant Engine (2020: 2) recommends that kitchen doors be sound proofed. Noise control fixtures such as mufflers, barriers, vibration isolation systems, enclosures, or factory walls with a higher sound transmission loss were not observed in any sampled kitchens.

9.5 Maintenance of equipment

With the exception of noise emitted by grinders and blenders, other kitchen equipment that were well maintained did not add to the loudness in kitchens as voiced by the head chefs. Table 9.11 indicates that improved maintenance of HVAC exhaust system can reduce noise in kitchens by frequent cleaning of extractors. Appendix 16 confirms that more than 51 % of the exhaust system was cleaned biannually.

The Chi-square test as indicated in Appendix 19 tests how likely it is that observed distribution is due to chance. As an indicator of "goodness of fit" statistic, it indicates how well the observed distribution of data fits with the distribution that is expected if the variables stated in Table 9.14 are independent with significance levels equal to but any value between zero and one.

According to Figure 9.7, nearly 90 % of the respondents agreed that the equipment was in good repair ($p < 0.001$). This did not seem true due to the audibly excessive noise from the extractors inferring worker acclimation to noise. Hearing loss could notably set in due to noise exposures above 85 dBA, as discussed earlier in section 9.3.1.

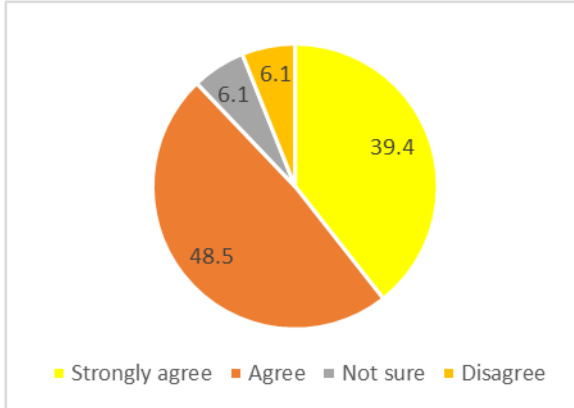


Figure 9.7 Head chef's opinion about equipment maintenance

The management of noise in the interval between the detection and correction of noisy equipment has not received attention in the literature. Appendix 20 indicates the waiting period for repair or replacement of equipment. Workers are usually not interested in doing anything about NIHL as it occurs gradually, is not visible and has an ambiguous time course in individuals (Purdy and Williams 2002: 78). Seixas *et al*. (2012: 643) found that employees be at moderate risk from non-occupational activities to NIHL.

Almost 40 % of kitchens shown in Appendix 20 to have a maintenance plan to repair or replace equipment within a week. Thirty percent (30 %) of the kitchens repaired the equipment in a day ($p = 0.017$). In a rare study, Seymour (2015: 1) reports on a survey undertaken that 67 % of chefs have replaced a piece of equipment in the past 12 months. The researcher contends that a common dilemma every commercial kitchen operator faces is when a piece of equipment slows down or fails completely, does it fall under maintenance schedule to repair in an attempt to extend its working life or replace it altogether.

9.5.1 Maintenance plan

More than 70 % of kitchens had a weekly maintenance program of equipment that helps to lower noise levels in kitchens (Table 9.14). Preventative maintenance prevents breakdowns and ensures that equipment is operational and safe to use (Walia *et al*. 2010: 1). The author further insists on planning for maintenance when purchasing the equipment. Eighty-nine (89 %) of the head chefs felt that the kitchen equipment is in good repair. This could be due to preventative maintenance as franchise food (24 %) enterprises have a policy as well as practice periodic maintenance. The ITW Food Equipment Group (2020: 1) asserts the significance of regular, scheduled preventive maintenance, an imperative practice for the efficiency, productivity, and quality of kitchens in terms of better noise control. Lack of good preventative maintenance will ultimately cost more to the food service operators (Diulio 2010: 1) as preventative maintenance is always easier than trying to fix a catastrophic problem after neglect.

Table 9.11 Frequency of equipment service intervals

Service Intervals	Frequency	Percent
Weekly	25	73.5
Monthly	1	2.9
Bi-annual	2	5.9
Yearly	1	2.9
When the equipment breaks down	3	8.8
Other	1	2.9
Total	33	100.0

Whilst Serfozo (2018: 1) confirms that the causes of noise substantially be attributed to improper maintenance, Fit for Work (2016: 1) add that regular maintenance reduces the risk associated with workplace hazards and provides safer and healthier working conditions for the well-being of the kitchen workers. About 11 % of the sampled head chefs believe that their kitchen equipment is in poor working condition. Insufficient maintenance can cause health problems or an increase in work accidents from continuous exposure to high sound levels. In this regard, regulation such as the Provision and Use of Work Equipment Regulations (PUWER 1998) and OHSA (1993) No. 85 - G 14918 compel effective maintenance of all work equipment. Almost 76 % of kitchens (Table 9.11) had a weekly maintenance plan to service kitchen appliances. According to Garbuzova (2017: 1), routine maintenance refers to scheduled maintenance for equipment and facilities to prevent equipment from prematurely breaking down.

The author adds that food manufacturers may have items like changing grease filters, fryer maintenance and boiler service as part of their maintenance schedule that in turn will reduce noise. Kister (2020: 1) agrees with the element of the weekly schedule completed with the Ready-to-Schedule (RTS) work order and coordinated accordingly. Hence, weekly maintenance as per Reyes (2014: 1) and Elkins (2019: 1) costs less than repairing or replacing kitchen equipment and HVAC.

A minority (8.8 %) practised breakdown maintenance and the remaining kitchens serviced medium size equipment monthly or as per the schedule with ($p < 0.001$). This means that auditory health of the kitchen workers is affected until the equipment is sent for repair. Gentile (2019:1) maintains that whether it is traditional restaurants or fast-food chains, different establishments must follow food service and health regulations on a daily, weekly, monthly and yearly cleaning and maintenance schedule. Levin (2017:1) claims that some food service directors emphasise making small maintenance checks as standard operating procedures and part of closing duties of kitchen workers. Good maintenance can reduce the physical hazard of noise. The Restaurant Times (2016: 1) reports on a restaurant industry association survey that chains have set up formalised processes and staff in place to manage repairs, spend 50 % less than the industry average.

The shortcomings in maintenance were found in the sample. In kitchens 14 and 28, the HVAC exhaust noise levels were 73 dBA, it was noisy as no maintenance programme was in place. In kitchen 25, the maintenance schedule was pending with noise levels of 83 dBA. In kitchen 16, the roof was made up of corrugated metal sheet which reflected some of the extractor noise into the kitchen (78 dBA).

The high value of 83 dBA observed in kitchen 25 was due to the exhaust fan requiring maintenance. The kitchen HVAC is a source of noise annoyance (Astolfi and Filippi 2004: 1203). The noise level far exceeded the permissible range of NR40 - NR50, equivalent to 40 dBA to 50 dBA set by the DEFRA (Gibson 2018: iv). Restaurant Engine (2020: 2) mentions that heating and air conditioning equipment should be maintained so that they work at their quietest.

With respect to the size of the exhaust system required in the kitchens, Gladieux (2015: 17) affirms that the flow rate of air and a centrifugal fan will influence the level and nature of noise emitted. According to Clark (2012: 58), reasonable noise levels are attained when the air velocity for Type I ducts is less than 2.54 m/s and not be more than 12.7 m/s The current study had maximum airflow rate of 2.5 m/s in kitchens which is too low to cause noise. Approximately 29.4 % of kitchen managers agreed that the electrical and mechanical equipment malfunction within 24 hours after service occurred.

The correlation between all the kitchen equipment is in good repair and work experience was found to be statistically significant, $r(33) = +.591$, $p < .001$, two-tailed. Thirty-eight (n=13) of the kitchen managers strongly agreed that all the kitchen equipment was in good repair. About 67.6 % of head chefs agreed that all the kitchen equipment was in good repair most of the time. Moreover, the researcher estimated that 76 % of the gas stoves and 70.6 % of the ovens were in good repair.

9.5.2 Equipment specification and installation

In both existing and proposed new installations, identifying noise sources and ranking them in order in terms of contributions to excessive noise is key to a noise control strategy (Hansen *et al*. 1995:

247). The smooth running of equipment is dependent on proper installation and maintenance (Webstaurant Store 2019: 1). The opinions of head chefs denote that 2.9 % of kitchens did not have all the equipment installed as per specification.

It was estimated that 88 % of the equipment was in good repair (Figure 9.7) but 5.9 % of the head chefs claimed that all equipment was not in good repair with chi-squared values of 19.485 and p=0.000. The possible reasons for this huge variation could be due to the impression that chefs may have about the equipment in use that may not be true. All kitchen equipment is installed as per specification which correlates positively with all the equipment in good repair (p=0.519 correlates with significance level of 0.002).

Using exploratory factor analysis, item 43.4, component 3, Good Maintenance has three loadings of 0.875, 0.752 and 0.693 for Equipment in good repair, Adequate lighting and Installation (Table 9.12). Implications of the component Good Maintenance beyond the noise construct to be discussed in section 10.5.1.

The adherence to the installation of equipment as per specification is a standard practice among head chefs with a 76.5 % compliance rate (Appendix 21) in commercial kitchens. Only one owner confessed that protocol not followed for installation of specific equipment due to unavailability of specification, although most equipment such as refrigerators, freezers, gas stoves, electric fryers and blenders generally found in commercial kitchens were installed as per specification.

Table 9.12 Rotated Component Matrix for noise and equipment condition

Rotated Component Matrix				
Q43.4	Component			
	1	2	3 Good Maintenance	4
1.All the kitchen equipment is in good repair	-0.120	-0.213	0.875	0.006
2.The amount of light in your kitchen is adequate	-0.152	0.204	0.752	0.080
16.All kitchen equipment is installed as per specification	-0.160	-0.057	0.693	0.134

According to Department of Higher Education and Training (DHET n.d: 4), it is obligatory on the owner that the equipment be installed as per specification and complete in all respects by the supplier or contractor. All equipment and the installation must conform to the OHSA of 1983, as amended (DHET n.d: 4).

The correlation between all kitchen equipment is installed as per specification with all the equipment is in good repair was found to be statistically significant, $r(33) = +.519$, $p < .002$, two-tailed. These two themes positively correlated. More than 90 % of the head chefs observed that all kitchen equipment were installed as per specification. Nonetheless, access to equipment specifications lay with the management and not with head chefs or kitchen managers due to frequent turnover of staff.

A properly prepared equipment specification will define the performance requirements of the equipment, materials of construction, fabrication methods and procedures, test and inspection requirements. Proper definition of these items will ensure that the equipment supplied will meet the performance requirements (Colt Engineering 2006: 1). The National Academy of Sciences (2019: 1) recommends that appliance noise emissions be specified and included in purchase specifications; however, this is not yet available in S.A. The noise emission values of appliances are required in Europe by law. Identifying these appliances are beyond the scope of this study.

9.6 Conclusion

This chapter established that noise levels in food service operations are high. Discomfort and staff complaints about noise were observed in some commercial kitchens. Most kitchen workers were unaware that hearing loss can occur due to noise in kitchens. Work experience in kitchens and age factor seems to influence noise adaptation among food service workers. Noise perceptions are defined by ethnicity. Kitchen spaces can affect noise comfort and good acoustics can actually reduce stress among kitchen workers. Maintenance and regular servicing of equipment help with reduced noise levels. The next chapter will discuss data analysis, presentation and interpretation of lighting.

CHAPTER TEN

DATA PRESENTATION, ANALYSIS AND DISCUSSION: LIGHTING IN KITCHENS

10.1 Introduction

The previous chapter discussed the data analysis of the noise variable in the sampled commercial kitchens. This chapter will present the findings of the study which was gathered from three researcher instruments and scientific test equipment. The findings will be presented according to kitchen work environment themes that emerged from investigations of lighting in kitchen areas, illumination requirements and maintainability

10.2 Lighting in kitchen zones

Among the most essential requirements for any kitchen workstation is lighting. Natural light is by far the best if possible (Homden 2017: 2). It is observable from Table 10.1 that the mean values of light measures from the present investigations are compliant with mentions of the SABS, SANS and HSG 38 regulations insection 5.9.2. Sampled kitchens that will be assessed in 10.2.3 demonstrate access to natural light indicates the best values for compliance.

Table 10.1 Mean lighting levels (lux) in kitchen zones

Work areas	Mean	Median	N	Std. Deviation	Minimum	Maximum	Range
Receiving	345.92	260.00	33	424.80	39.00	1790.00	1751.00
Preparation	322.85	240.00	33	241.44	25.00	1003.00	978.00
Stove	204.23	190.00	**31**	94.83	25.90	410.00	384.10
Oven	281.57	189.50	**30**	217.72	30.00	960.00	930.00
Holding	284.60	185.00	33	319.60	36.00	1613.00	1577.00
Dishwashing	211.19	190.00	33	150.42	28.00	630.00	602.00
Corridor	298.96	180.75	32	394.74	25.00	1985.00	1960.00

Lighting emerging from different permutations of sunlight and artificial light in Appendix 25 illustrates variation in area of the kitchen. Nonetheless, the mean intensity of lux measures in receiving areas was the highest (Table 10.1). However, due to the observed wide variation in the minimum and maximum values, the suitability of the mean values cannot elicit information on lighting levels from the perspectives of worker eyestrain, headaches, tiredness, irritability and ergonomics in different kitchen areas.

The requirement for corridors by SANS and SA legislation is 100 lux (South Africa OHSA Act 1993) which is much lower than the observation of 298.6 lux. This could be due to the presence of sunlight. The mean lighting levels (lux) in kitchen zones are suitable for worker lighting comfort as the values are well above the SANS criteria and seem reasonable in terms of illuminance, the minimum values are much lower than 100 lux indicating poor lighting from a particular restaurant. The higher values are due to the presence of sunlight as well as spotlights, which points out that in some sampled commercial kitchens worker discomfort from inadequate lighting is likely. HSG38 (1997: 38) recommends average lighting of 20 lux in corridors which is much lower than 100 lux recommended by OHSA (1993: 10) No. 85 of 1993.

The UV lamps in the holding area contributed considerably to the mean of 284 lux. Better light emits from grease-free lighting sources. Similarly, large differences in lighting levels in receiving areas could be due to the presence of sunlight from the open door, glass walls and windows. The holding, corridor and receiving areas elicited highest standard deviation values due to a huge difference in the minimum and maximum values in Table 10.1 (page 264). The found standard deviation is suitable in five kitchen zones for worker lighting comfort, except the stove area where the lighting value (95 lux) is below SANS criteria.

Figure 10.1 (page 268) uses the subjective estimation of the researcher. Allan *et al*. (2019: 151) advances that subjective evaluations of lighting are an important complement to objective photometric information. Dianat *et al*. (2013: 1535) suggest that quantitative physical measurements be supplemented by qualitative subjective assessments to provide a more holistic approach to the lighting condition in the working environment. Following Allan's *et al*. (2019: 151) subjective estimation of lighting adequacy recorded for researcher observations in Figure 10.1. More than 65 % of the kitchens have lighting in food preparation areas categorised as being adequate (323 lux). More than 34 % of the kitchens had dim lighting in preparation areas and 57 % had dim lighting in cooking areas.

Almost 43 % of the kitchens have adequate lighting in cooking areas (204 lux). Lamps inside the canopy hoods provided most of the lighting. The stove area in Table 10.1 has the lowest mean due to the presence of canopy hoods that prevent light from illuminating the ranges and stoves as well as due to the absence of lighting fixtures in the canopy hood. Three kitchens had lighting fixtures with fused light bars. Kitchen managers and head chefs seem to assume that the presence of general lighting will suffice in the stove area. This is an unfavourable assumption for worker lighting comfort. According to Radcliff (2018: 1), lighting areas such as stoves, and kitchen islands where cooking and preparation takes place requires plenty of lighting and lights often fall short of providing sufficient light. There was no dedicated lighting for oven areas but these areas received lighting from general areas.

Most ovens have an Appliance Rated Lamp inside that provides lighting in the oven. In this regard, Home Improvements (2013: 1) specify that internal oven light must never be a CFL or LED which are not usable in high heat environments. All the ovens in operation mode in the sampled kitchens seem to have rated lamps working. The analysis of lamp rating is beyond the scope of this study.

The correlation was undertaken between adequate lighting on food preparation areas and adequate lighting on cooking areas was found to be statistically significant, $r(32) = +.677$, $p = .001$, two-tailed. This is a positive indication for worker lighting comfort in kitchens.

Table 10.2 Rotated Component Matrix on facility design and layout

	Component		
	1 Area Illumination	2 Precise Fixtures	3 Light Specifications
13. Adequate lighting on food preparation areas	0.955	0.023	0.192
14. Adequate lighting on cooking areas	0.932	0.126	0.275
15. Adequate lighting on dish washing areas	0.895	0.249	0.157
16. Are all lights protected from breakage	-0.140	0.482	0.329
17. Adequate artificial light at night	0.631	0.046	0.710
18. Adequate light during load shedding at night	0.355	0.073	0.664
19. Presence of Task Light	0.224	0.947	0.085
20. Presence of Infra-red light	0.224	0.947	0.085
21. Presence of UV light- keeping food hot	0.131	0.250	0.830
Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.			
a. Rotation converged in 6 iterations.			

Further to individual investigation of each task area conveyed in Table 10.1 (page 264), exploratory factor analysis was applied to survey items relevant to lighting in the kitchens. The result of the analysis revealed factor loadings of 0.955, 0.932 and 0.895 respectively in preparation, cooking and dishwashing areas in kitchens (Table 10.2). These were categorised into component 1, namely Area Illumination. Less than 40 % of kitchens had adequate lighting in dishwashing (DW) areas. DW areas in kitchens seem to have the lowest amount of lighting when compared to other areas in the kitchens surveyed. James (2017: 2) claims that rummaging in a dark dishwashing machine is never a happy experience. While Ghosh (2019: 1) insists that it is important to ensure that the work area is lit up properly, Payne-Palacio and Theis (2016: 204) suggest the provision of adequate lighting for all storage area tasks and maintenance of effective lighting so that the results of cleaning programs is easily inspected. The authors' statement did not align with the findings in the study, as almost 10 % of the kitchens seem to have unsatisfactory lighting in all the different zones.

Exploratory factor analysis further generated factor loadings of 0.482, 0.947 and 0.947, respectively, for lights protected, presence of task light and presence of infrared light; these were categorised into component 2, Precise Fixtures. 15.2 % of the kitchens had the presence of task light, and 12.1 % of the kitchens were observed to have installed infrared light (Figure 10.1) to be discussed in section 10.3.4. Local lighting was not provided in more than half the kitchens in preparation, cooking and dishwashing areas. In this regard, task lighting will be discussed in section 10.5.2. The component 3, Light Specifications will be discussed in section 10.3.4.

10.3 Visibility

Similar to the investigations of Kim and Mansfield (2016: 9), Allen *et al*. (2019: 124), and Katabaro and Yan (2019: 6), the Likert scaled researcher observation in Figure 10.1 indicate wide variations in scoring patterns from the sampled kitchens. The first seven statements illustrate higher levels of "good" rating for the first 6 and a significantly greater level of "unsatisfactory" for statement 7 ($p < 0.05$). There was no significant difference in the scoring for the last two statements ($p < 0.05$). Dishwashing areas in almost 17 % of the kitchens were inadequately illuminated. UV heat lamps were prevalent when compared to halogen lamps in the pick-up section. Webstaurant Store (2020: 2) claims that halogen elements can be much more efficient so that food is kept just as hot.

Nisbets (2019: 1) claims that good visibility is paramount to a kitchen. Pachito *et al.* (2018: 1) is of the opinion that daytime workers may be exposed to insufficient or inappropriate light during daytime, leading to mood disturbances and decreases in levels of alertness.

The sections to follow will discuss illumination and fitting arrangements, inadequate lighting in kitchens, natural light, artificial lighting, and effective lighting in work areas.

10.3.1 Illumination and fitting arrangements

Cooks constantly rely on their sight to determine the quality of the food, the ingredients, to navigate through the kitchen and to use the equipment and tools correctly (Ring 2018: 20). Eighty-seven percent (87 %) of the kitchen workers believed that general lighting was adequate in their kitchens (Figure 10.2). Kitchen interior design is significant in this regard. According to SABS (2005: 29), kitchen lighting above 150 lux is categorised as being adequate. For instance, because light reflects off walls, ceilings, floors and surfaces, the choice of colour, material and finishing of these surfaces must be carefully considered as the reflectance can be a factor in the luminance level of the area. The detail of this aspect is beyond the scope of this study. Boyce (2003: 4) confirm that lighting and task conditions that improve visibility lead to better task performance.

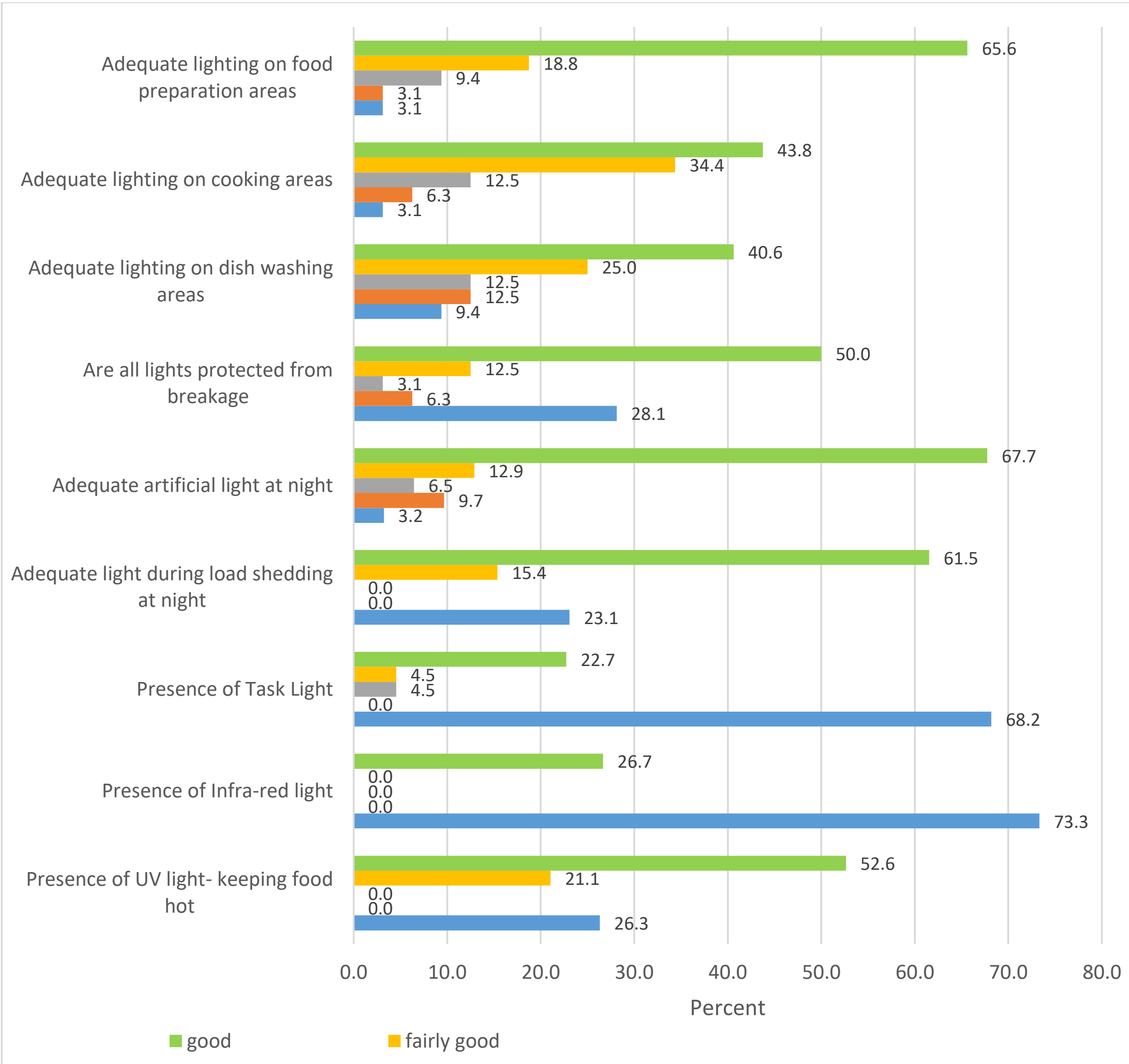


Figure 10.1 Researcher approximation of lighting in kitchens

The researcher estimated that 87 % of the kitchen had adequate general lighting (Figure 10.1); 215 lux is required on all work surfaces in areas (Manitoba 2016: 10). Additionally, a minimum of 540 lux is recommended at a surface where a food employee is working with food or working with utensils or equipment such as knives, slicers, grinders or saws where employee safety is a factor (US Food and Drug Adminisration 2017: 186). The current research recorded mean lighting levels of 286 lux at fryers and 211 lux at grillers. There is an obvious dearth in the literature on lighting levels specific to cooking areas.

Storage areas, washrooms and dining areas must be provided with lighting levels of 150 lux to allow for proper cleaning operations as per the Occupational Health and Safety Act No. 85 of 1993. The present study found that lighting levels seemed to meet the requirements in all task areas except in one kitchen; measurements taken indicate compliance with SABS recommendations, however, it falls short of complying with OHSA recommendations indicated in Table 5.3.

Nevertheless, 96 % of workers estimated that there was good general illumination throughout the kitchen (Figure 10.2). Several authors including Lorentz (2011: 13), Maierova *et al*. (2013: 8) and Standard (2019: 1) emphasise that the kitchen environment must be evenly illuminated to support visual control of food while simultaneously supporting worker safety factoring ergonomic design principles.

Safety of lighting designs in commercial kitchens advanced in the FDA Food Code Chapter 6 Section 202.11 (US Food and Drug Adminisration 2017: 180) promulgates that light bulbs should be shielded, coated, or otherwise shatter-resistant in areas where there is exposed food; clean equipment, utensils and linens. A significant number (62.5 %) of kitchens in the present study were observed to have all the lamps protected from breakage; however, 21 % had a few unprotected lamps (Figure 10.1 page 268). Almeida *et al*. (2014: 349) report similar results wherein school food services had unprotected lamps.

10.3.2 Inadequate lighting in kitchens

Black and Decker (2009: 241) claim that many kitchens are poorly lit. One common kitchen lighting problem is the centrally placed ceiling fixtures with no other lighting sources. Unfortunately, this central fixture creates strong shadows at workstations because the cook's body is always between the light source and the work area. While artificial lighting in kitchens is bound to assist, early studies by Eagles and Stedmon (2004: 442) find that the artificial lighting in a restaurant kitchen of 180-286 lux was substantially below recommended levels of 300-500 lux (Engineering Toolbox 2004: 2). The lack of local lighting in 70 % of the kitchens suggest inadequacy in the number of light sources. The preparation areas in kitchens are especially hazardous in the absence of adequate lighting, for example, to avoid accidents among workers who might be doing delicate tasks with sharp knives (Colin 2011: 2). Lighting is crucial to the safety of kitchen employees, especially those working with sharp objects (Hood Cleaning Supplies 2018: 1). A graver shortcoming of similar commercial kitchens investigated by Almeida *et al*. (2014: 349) albeit in Brazil finds that 97.3 % of do not comply with lighting requirements. In contrast, lighting described as adequate was found in 77.4 % of food establishments in Ethiopia (Kumie and Zeru 2007: 4). Sebitosi and Pillay (2007: 677) nonetheless caution that due account must be taken of standard variations between countries.

Additionally, disclosures of commercial kitchen lighting from multiple studies suggest that its importance seems to be ignored by management. Although HSG38 and OHSA recommend 100 lux (International Labour Organisation OSH Brief No. 3c 2017) in kitchens, Gaydos *et al*. (2011: 62) reported that of the 106 restaurant kitchens in San Francisco's Chinatown, 28 % lacked adequate lighting. Additionally, Omidiandost *et al*. (2015: 257) found hospital kitchen lighting to be 148 lux compared to the recommended 250 lux.

10.3.3 Natural light

The result of exploratory factor analysis (Table 10.12 page 286) revealed a factor loading of 0.818 for the presence of natural light and the presence of direct glare respectively; they are categorised as illuminance. Commercial kitchens are often too large to be completely illuminated by natural light; therefore, glare and shadows are going to be a constant problem, moreover, natural light is not available twenty-four hours a day (Balogh 2008: 62).

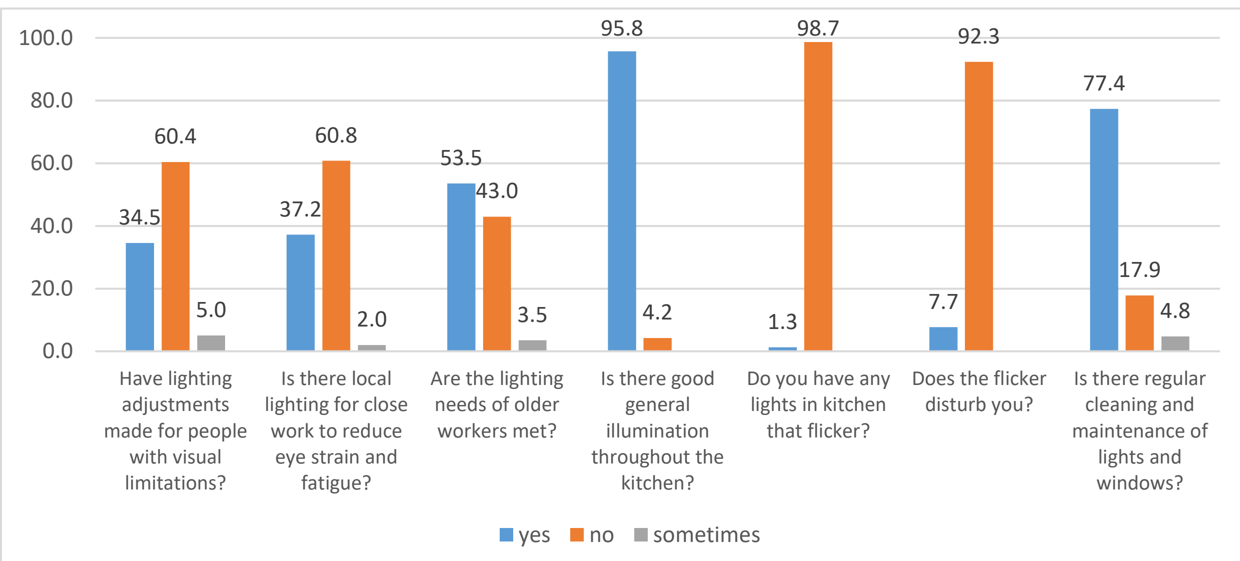


Figure 10.2 Worker's opinion on lighting conditions in kitchens

The design of the sampled kitchens favoured daylight. Hammer and Holzer (2020: 980) urge that there is a rising need to deliberately design indoor environments for sufficient daylight quality. Almost 73 % of restaurants in the current study had glass walls or large windows permitting light into the kitchens, and only 15 % had skylights in the kitchens. However, the kitchens were not all fitted with windows; 50 % of them had no windows or the windows were covered for privacy. Hence, natural sunlight was denied to the staff. Daylight is superior to alternate lighting systems as it contributes to happier workers, fewer illnesses, satisfaction among workers, and increased productivity (Jensen 2019: 1). Haslam (2013: 1) claims that sunshine boosts positive moods and diminishes tiredness. According to the researcher's estimation, 10.3 % of kitchens had fairly good natural light while 34.5 % had somewhat satisfactory natural light (Figure 10.5).

However, Nabil and Mardaljevic (2006: 905) lament that daylight is a greatly under-exploited natural resource. On the other hand, high levels of daylight illuminance are known to be strongly associated with occupant discomfort (> 2000 lux). Hence 100 lux is recommended in HSG-38 (1997: 38) to avoid visual fatigue and provide adequate illuminances for safety purposes for kitchen workers. Almost 15.2 % of kitchens had optimistic lighting levels in kitchens due to the influx of sunlight (Table 10.3). Most areas in kitchens met the lighting criteria for 300 lux to 500 lux as recommended by SANAS, OSHA, WHO, CIBSE, BOSH and Australian Standards.

Table 10.3 Lighting levels (lux) in kitchens with optimal natural light

Kitchen Code	Receiving	Preparation	Cooking	Dishwashing	Mean (kitchen)	Daylight Source	Artificial Lighting
2	270	480	500	230	**370**	Open-plan, open front doors, 1 back door, 2 windows	Recessed louvre double fluorescent lights
4	640	900	360	610	**627**	Hatch, windows absent	Recessed louvre double fluorescent lights
11	1770	460	280	300	**700**	1 Back door, 4 windows	Recessed louvre double fluorescent lights, suspended fluorescent lights
14	260	510	230	428	**357**	Double back doors, 1 skylight, 4 windows	Suspended fluorescent lights
25	301	730	560	125	**430**	Open-plan, open front doors, glass wall, 1 back door, no windows	LED Panel lights
26	340	1003	460	375	**545**	Open-plan, open front doors, glass wall, double back door, no windows	LED Panel lights
27	1790	760	360	330	**810**	Double back door	Fluorescent lights
Mean (areas)	**767**	**690**	**390**	**340**			

The commercial kitchens in Table 10.3 are well-designed with proper implementation of lighting for the staff to efficiently and safely perform their tasks of food preparation, cooking, presentation and cleaning. At the same time, reflections and glare were absent. Kitchen 27 did not use artificial lighting at daytime unless the sky is gray/overcast. Due to the location of the kitchen in the commercial complex, kitchen 4 had bright artificial lights and no windows. The presence of glass walls in the front and open back doors flooded different kitchen areas with sunlight depending on the layouts.

Skylights, windows and windowed doors all provide natural sources of light to enhance a kitchen space. For east and west oriented kitchens, the light will be brighter and more intense in either the morning or evening. South facing kitchens are ideal for energy-saving and the light coming in north-facing kitchens will be indirect for most of the day (RH Homes 2020: 4). Be it natural daylight or artificial lighting, brightness is experienced subjectively. In the kitchen, the work lights should be integrated into the extractor hood (Engel and Völkers 2020: 3). For the best balance, at least three sources of light should be available in every space including sunlight. Dimmers can change the balance between artificial light with natural light in the day (Better Homes and Gardens 2020: 3).

The relationship between artificial lights and natural lighting is important when installing commercial kitchen lighting. While it is true that artificial lights will be the primary source of light in a kitchen, natural lighting can also play an important part. If possible, the kitchen window should be at least 10 % of the total wall area in the kitchen. Windows should look out an open space or the sky (Die-Pat 2016b: 1). However, the Australian Government Guideline (2010: 10) observes that the successful integration of daylight and electric light in rooms will depend not on the balance of daylight and electric light illuminances, but on the achievement of a satisfactory brightness distribution.

10.3.4 Artificial lighting

Munch *et al.* (2020: 65) find that people with daylight activity were significantly more alert, and subjects exposed to artificial light (AL) were significantly sleepier at the end of the evening. Nonetheless, access to natural lighting as well as artificial lighting is essential to ensure the well-being of occupants in areas where natural lighting is missing or during the evening when the natural lighting fades (Aries *et al.* 2010: 533). Blitzer and Mackay (2015: 37) posit that the daylight from windows and skylight be replaced at night by additional lighting. In this regard, Kort and Smolders (2010: 345) contend that preferences for artificial lighting vary with weather type, brightness and time of the day. Notably, the two most common scenarios for poor lighting are lights that are too dim and lights that are too harsh.

Table 10.4 Presence of UV light- keeping food hot

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Unsatisfactory	5	15.2	26.3	26.3
	Fairly good	4	12.1	21.1	47.4
	Good	10	30.3	52.6	100.0
	Total	19	57.6	100.0	
Missing	System	14	42.4		
Total		33	100.0		

Giving impetus the need for artificial lighting, exploratory factor analysis (Table 10.2 page 266) revealed component 3, named Light Specification the component derived from the factor loadings of 0.710; 0.664 and 0.830, respectively, for artificial lighting at night, adequate light during load shedding at night and heat lamps for keeping food hot. Almost 63.6 % of the kitchens had adequate artificial light at night; 30 % had rechargeable LED in addition to lights connected to a generator. Thirty-percent (30.3 %) of the kitchens had heat lamps for keeping food hot (Figure 10.1 page 268, Table 10.4). Nisbets (2019: 1) observes that emergency lighting can turn on automatically from its own power supply whenever there is a power failure. Comparisons cannot be made due to the lack of relevant published literature in a kitchen context.

Artificial lighting in 30.3 % of the kitchens comprised of heat lamps for keeping food hot. Lighting in holding areas in 18 % of the kitchens in Table 10.4 was very high due to the presence of UV light. Heat lamps seem to increase the heat in the area as well. Almost 53 % of kitchens had UV lamps and 26 % had infrared lights. Only two kitchens had halogen lamps. UV heat lamps were popular compared to halogen lamps to keep food hot without drying in the holding area. Technilamp (2020: 1) recommends that food-warming lamps use infrared technology to keep food at the right temperature, for accompaniments, vegetables, bread, and for plated dishes ready to leave the kitchen.

10.3.5 Effective lighting in work areas

In addition to general lighting, every work surface in the kitchens were well illuminated by task lighting (The Lighting Warehouse 2018: 1). Lighting from any source will cast shadows and produce a glare on shiny surfaces, which can reduce the visibility of the task and cause eyestrain. Several sources of task lighting will ensure that worker’s hands or other objects do not shade their work (Mitchell 2012: 11). This section will therefore analyse the findings associated with lighting effectiveness.

Table 10.5 Opinion of head chefs and kitchen managers on kitchen lighting

Opinion of head chefs	YES	%	NO	%	P-value
Are work areas free from shadows?	30	90.9	3	9.09	0.000
Can employees comfortably see their work without straining?	31	93.9	2	6.06	0.000
Mobile task lighting provided?	5	15.2	28	84.8	0.000

Although it seems that it is a common practice to not emphasise discussion on dangerous pieces of equipment and areas are well-lit to alert employees to the hazards, awareness about the risks involved would elicit a positive response from head chefs and workers.

As stated in 10.3.4, workplaces should receive natural light where feasible and be supplemented with sufficient artificial illumination to promote workers' safety and health and facilitate safe equipment operation. Table 10.6 depicts the association of the presence of natural lighting with the presence of sunlight to model improved lighting in preparation areas. Consequently, the preparation of high-quality food in poorly lit kitchens, can be challenging. However, the researcher's appraisal revealed that 85.2 % of the kitchens with no skylights had unsatisfactory lighting in some kitchen zones (Figure 10.6). Despite the importance of skylight in the provision of natural lighting in kitchens, no studies investigated this association. Black and Decker (2009: 245) endorse that skylights work well in kitchens because they dramatically brighten the room even on cloudy days. This would improve the kitchen design performance on the functionality of a kitchen room. Additionally, skylight installations facilitate the transmission of natural light into rooms at the centre of a building that would otherwise be windowless (Ander 2016: 1).

Table 10.6 Correlation coefficient for lighting in preparation area

Coefficients[a]								
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	108.121	126.259		0.856	0.410		
	Presence of Natural light	134.058	50.044	0.660	2.679	0.021	0.836	1.196
	Presence of skylight	-104.870	47.577	-0.543	-2.204	0.050	0.836	1.196
a. Dependent Variable: lighting (lux) in preparation area (Q93.2) b. Predictors: (Constant), AB25 = presence of natural light, AB26 = presence of skylights								

$Y_{predicted} = b0 + (b1*x1) + (b2*x2)$

The column of estimates provides the values for b0, b1 and b2 for this equation.

The equation is written as: Preparation area lighting = 108.121 + (134.058 × Natural Light) + (-104.870 × Skylight). This equation helps to compose indoor environmental criteria for design of restaurant kitchens in Durban in respect of lighting. The equation has predictive potential that contributes towards Objective 1 and Objective 4.

The coefficient for natural light is 134.058. It is accordingly anticipated that for every unit increase in natural light, a 134.058 unit increase in lighting in preparation area value is predicted, holding all other variables constant at a 95 % Confidence Limit for predictors.

The modelled predictor indicates that for every unit increase in skylight, a -104.870 unit decrease in lighting needs in preparation area is predicted, for good vision holding all other variables constant. In support, Yazıcıoğlu and Kanoğlu (2016: 35) recommend at least 8 % of the total area of an open or closed kitchen must be an area allocated for windows or skylights. The coefficient for Skylight (-104.870) is not significantly different from zero because its p-value is 0.050, which is greater or equal to 0.05. This p-value indicates that the observed difference or more in 5 % of studies observed due to random sampling error. The intercept is not significantly different from 0 at the 0.05 alpha level. The coefficient for Natural Light (134.058) is significantly different from zero because its p-value is 0.021, which is smaller than 0.05. This p-value indicates that the observed difference or more in 2.1 % of studies observed due to random sampling error.

Tests for multi-collinearity indicated that a very low level of multi-collinearity was present namely, Variance Inflation Factor (VIF) = 1.196 for presence of natural light and 1.196 for presence of skylights. Although, Akinwande *et al*. (2015: 756) found that if the VIF is greater than one, the regression is moderately correlated; Allison (2012: 1) asserts that statisticians tend to get concerned only when a VIF is greater than 2.50, as multi-collinearity exists. Beta coefficients for the two predictors were presence of natural light, $\beta = 134.058$, $t = 5.539$, $p < 0.21$; presence of skylights $\beta = -104.870$, $t = -2.204$, $p < 0.21$. The best fitting model for predicting lighting requirements in the preparation area of a commercial kitchen derived from a linear combination of the presence of natural light and skylights.

10.4 Visual comfort

Eleven questions evaluated visual comfort in the interview schedule. Boyce (2003: 4) confirm that comfort and visibility scores dropped from the morning to the afternoon. The direction of both effects is consistent with the development of fatigue over the working day. This section will accordingly discuss lighting awareness, eyestrain and flickering lights.

10.4.1 Lighting awareness

The level of lighting that workers require varies depending on the nature of the task, the sharpness of the workers' eyesight, and the environment in which the work is undertaken (Unicamp 2016: 1). The lack of worker awareness has potential for a range of vision-related symptoms such as eyestrain, headaches and nausea that may worsen as the day progresses.

There appears to be minimal kitchen worker sensitivity to the role of light in their task environment as evidenced by 70 % of the workers' response that they are unaware of good lighting. Some kitchens did not have adequate lighting levels and this shortcoming appears to have affected some workers who strained to work and sometimes even had headaches. The lack of worker awareness has potential for a range of vision-related symptoms such as eyestrain, headaches and nausea that may worsen as the day progresses (International Labour Organisation: 2017). Light bulbs not replaced until they burn out is due to ignoring the reduced effectiveness of light as the bulb ages. Chefs and workers are not aware of these changes and continue to work without replacing them.

10.4.2 Adaptation to lighting

The head chefs and kitchen managers opine that almost 60 % of the reason for adaptation to lighting is due to other factors. However, they could not define these other factors and were unable to assign a specific reason. There is a dearth of literature on kitchen worker adaptation to lighting. Almost eighteen percent (17.6 %) believed that that tenure of work in commercial kitchens enable workers to see in the available lighting in kitchens. Unsurprisingly, therefore, while age is an important determinant of vision, only 8.8 % believed it influenced vision and will be explained in 10.5.4. A probable contributor to this view may be that only two staff members above the age of 60 years lamented that they strained their eyes due to inadequate lighting.

Table 10.7 Adaptation to lighting according to head chefs

Personal factors	Percent
Age	8.8
Work experience in kitchen	17.6
Work activity	5.9
Physical fitness	8.8
Health status	2.9
Other	58.8

10.4.3 Lighting needs of older kitchen workers

Also, 76 % of the workers felt that the lighting needs of older workers were met (Figure 10.2). The age of kitchen workers in table 7.1 varied from 19 to 62 years with a mean of 31 years ± 8.55. More than 60 % of food service workers report that lighting adjustments for people with visual limitations especially, older workers were not provided.

With aging, the structures of the eye wear out, so affecting the amount of light to be processed (Lightology 2018:1). Average visibility according to Boyce (2003: 39) is always higher for young people than for older staff > 40 years. On the other hand, Kunduraci (2017: 185) claims that an average 60-year old eye requires three times more illuminance than an average 20-year old eye. Cones and rods, the light receptors in the eye, begin to die off as people age, which explains why older people need more illumination than younger people (Owen 2012: 2).

Consistent with the present study, a survey by Hrovatin *et al.* (2012: 113) found that 32 % of elderly people complained of inadequate lighting over the kitchen work surfaces. According to the American Optometric Association (2020: 2), eyes and vision change over time and workers need more light to see.

Vision functions such as visual acuity, colour discrimination, contrast sensitivity, and visual fields show characteristic decreases as people age, the quality of demanding kitchen work performance by older workers may be threatened along with their level of visual discomfort (Lorentz 2011: 2). It seems that existing minimum lighting design regulations are unlikely to satisfy elderly kitchen worker needs. Elderly work-going persons may be exposed to very low levels of illuminance in a space and adapt to low levels of illumination.

Additionally, Lorentz (2011: 2) asserts that older workers also exhibit heightened vulnerability to adverse viewing conditions. This is exacerbated in hostile viewing conditions such as glare, excessive brightness and dim lighting conditions. The literature mentions are sparse on variables in Table 10.7 (page 276) such as work experience in kitchen, work activity, physical fitness and health status.

10.5 Visual discomfort

As per Kumar *et al*. (2020: 168), improper lighting conditions either too bright or too dark can create visual discomfort. Health and Safety Guidelines (HSG 1997: 4) claims poor lighting can cause a number of problems, such as eyestrain, headaches, tiredness and irritability. Aries (2005: 54) confirms that a poor lighting environment may reduce accuracy, increase the time to do a task and cause fatigue or eyestrain. The loss of lighting in preparation areas by the cleanliness of lighting globes and fixtures became evident in a multivariate regression model. The model also provided evidence that dim lighting in preparation areas or too much bright light can cause headaches among kitchen workers.

The multivariate regression model Y = b0 + b1*x1 + b2*x2 that Lighting in preparation area = (-881.86) + (92.341 x headaches) + (112.088 x clean lights and fixtures). The inverse relationship reflects that lower levels of lighting is needed in preparation areas when the lights and fixtures are clean and bright lights cause headaches. In highlighting the association of human well-being in the workplace (headaches) with a preventable cause (clean lights and fixtures), Table 10.8 indicates needed procedures for extension of cleaning practices.

Table 10.8 Correlation coefficient with headache and clean lights in kitchens

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-881.864	448.755		-1.965	0.075
	Headaches Q29.1	92.341	41.137	0.473	2.245	0.046
	Lights clean and fixtures Q30.4	112.088	38.717	0.601	2.895	0.015
a. Dependent Variable: lighting (lux) in preparation area in kitchens Q92.2 b. Predictors (Constant), Q29.1 = Headaches, Q30.4 = Lights clean						

The main objective should be comfortable and effective illumination by setting the right fixtures in the right places and about maximising natural daylight. The model will also add to needed indoor environmental criteria for design of restaurant kitchens in Durban in respect of lighting. The equation can potentially contribute to addressing Objective 1 and Objective 4.

The coefficient for headache is 92.34. For every unit increase in headache, a 92.341 unit increase in lighting in preparation area value predicted, holding all other variables constant. Photophobia, or light sensitivity, is an intolerance of light. Sunlight, fluorescent light and incandescent light all can cause discomfort and may accompany headaches (Bailey 2019: 1). Further to eyestrain in Denny Vision (2019: 2), exposure to harsh fluorescent lighting or flickering can also cause headaches.

Working in a dimly lit environment as well as working under bright lights can be equally uncomfortable. Dim light can cause eyestrain and make the eyes tire quickly. LEDs are more likely to cause headaches than fluorescent lamps (Wilkins 2017: 3). Similarly, for every unit increase in clean lights and fixtures, a 112.08 unit increase in lighting in the preparation area is predicted, holding all other variables constant. Seventy-one percent (71 %) of the kitchens had clean bulbs and almost

66 % of kitchens had clean fixtures. Figure 10.2 indicates that almost 18 % of the kitchen workers assumed that the light bulbs are not cleaned on a regular basis. Green Seal (2014: 12) recommends that lighting fixtures, diffusers and lamps be cleaned once a month. Access to natural ventilation means dirty lamps and fixtures. Selection of direct/indirect fixtures that allow airflow instead of through the fixture past the bulbs to minimise dirt accumulation as per Los Alamos National Laboratory Sustainable Design Guide (2018: 86).

It is important to keep light fixtures clean as they can set the tone for a room (Merry Maids 2019: 1). Dirty light fixtures can also lessen the amount of light a room receives and lower the lifespan of light bulbs (Aguirre 2018: 1). Dirty light bulbs can give 20 % less light than clean bulbs, so regular cleaning brightens spaces (Home and Garden TV 2019: 1). Good lighting can decrease eyestrain and headaches, nausea and neck pain that often accompany eyestrain.

The coefficient for headaches (92.341) has a p-value 0.046, which indicates that the observed difference or more in 4.6 % of studies observed due to random sampling error. The coefficient for clean lights and fixtures (112.088) is significantly different from zero because its p-value is 0.015, which is smaller than 0.05. This p-value indicates that the observed difference or more in 1.5 % of studies observed is due to random sampling error.

10.5.1 Local lighting and task lighting

The production of high-quality, well presented food is pivotal in all commercial kitchens, making proper work area lighting an essential, as is the ergonomic design of kitchen-area lighting to accommodate the safety of the staff and food (Earth Tronics 2014: 2).

Table 10.9 Local or task lighting for close work

Estimation		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	55	32.2	37.2	37.2
	No	90	52.6	60.8	98.0
	Sometimes	3	1.8	2.0	100.0
	Total	148	86.5	100.0	
Not sure		23	13.5		
Total		171	100.0		

Almost 61 % of the kitchens had unsatisfactory task lighting (Table 10.9), although all the kitchen workers were complacent about personal control of lighting as switches were easy to reach.

Three staff found that local lighting varied with the allocation of their workstation. Figure 10.3 indicates that only 30 % of kitchens had provision for local lighting and only one kitchen had windows and skylights whitewashed to avoid glare. Even though skylights and windows can offer an improved working environment for staff by allowing natural light into the workspace, if poorly positioned, they can result in a good deal of glare (Die-Pat 2016b: 1). A minor proportion (15.4 %) of the kitchens provided for dangerous pieces of equipment and areas to be well lit to alert employees to the hazard. In all instances, more responses were "No", with the differences being significant for the last two statements (p = 0.05).

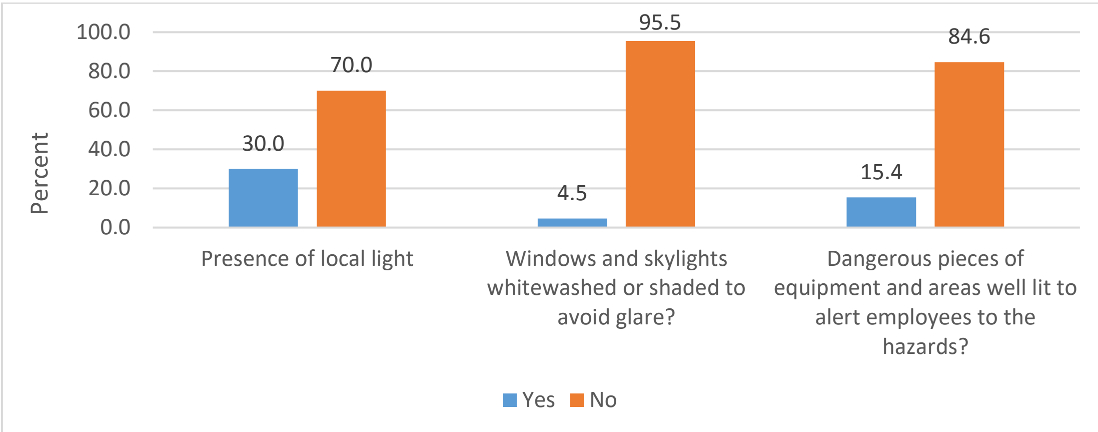


Figure 10.3 Researcher's observation on lighting arrangement in kitchens

A lower percentage of 'no' in Table 10.5 (page 274) could be due to the head chefs and kitchen managers unacquainted with inadequate lighting in kitchens. It seems that appropriate action was lacking due to the ignorance of lighting requirements in kitchen areas. According to CELMA (2011: 8), dynamic lighting over the working day supports, stimulates and motivates workers throughout the working day; mistakes in demanding visual tasks can lead to loss and gives additional support to the well-being of the worker and a better work condition. Lighting awareness triangle consists of performance, efficiency and comfort (CELMA 2011:19) that may be deficient among kitchen staff.

10.5.2 Task lighting

Webstaurant Store (2018: 1) states that task lighting allows staff members to perform functions that may need a more concentrated light source, like cooking. In addition, personalised lighting is facilitated by providing a dimming control through task lighting while lowering the level of ambient lighting (Boyce 2003: 162). Such lighting may be necessary for delicate kitchen work. Over half of the workers (52.6 %) **(**Table 10.9 page 279) complained that no local or task lighting was provided at their workstations. Eighty-three percent (83 %) of head chefs additionally responded that mobile task lighting was not provided. The opinions of kitchen managers and head chefs about visual comfort in kitchens were positive (94 %). The researcher's approximation using an observation checklist indicated (Table 10.2) that 68 % of the kitchens had unsatisfactory task lighting. Katabaro and Yan (2019: 8) recommend that ambient-task lighting should be installed as it offers the advantage of providing illumination where it is needed most. This kind of lighting design was also reported in CIBSE (1994) as being an efficient method of increasing occupants' level of comfort, work environment satisfaction, and improved work efficiency.

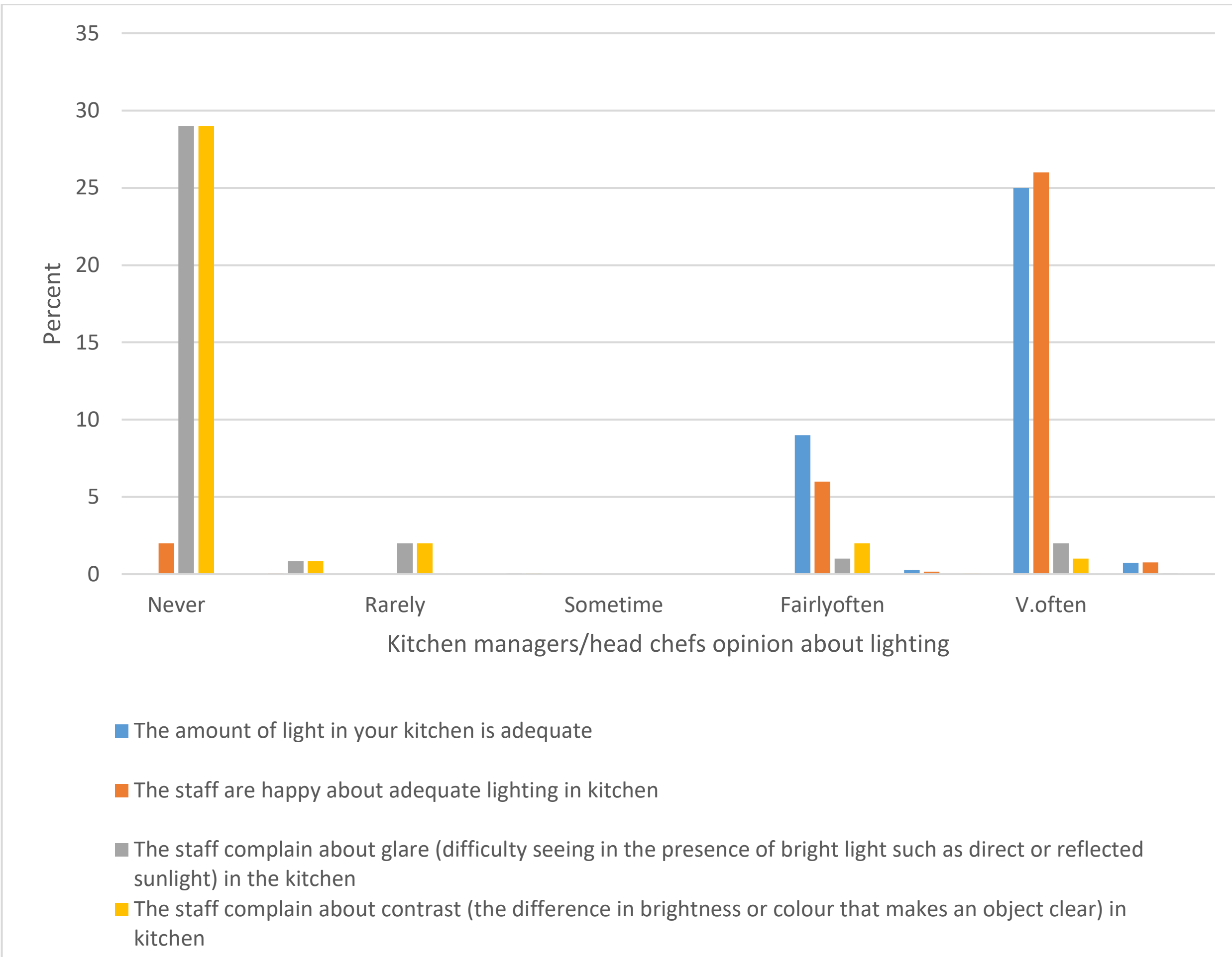


Figure 10.4 Head chefs and kitchen manager's opinion about glare and contrast

A majority (84.8 %) of head chefs responded that mobile task lighting was not provided. Afacan and Demirkan (2010: 325) assert that it is not possible to ensure an adequately illuminated kitchen by only providing adequate natural and artificial light. It also depends on the task lighting above counters and cook-tops where visibility is required. Task lighting with a dimming provision will maintain ambient lighting from being too bright and personalise lighting needs (Boyce 2003: 162). Task lighting that illuminates the whole worktable might be acceptable.

Within a kitchen environment, Hima Bindu and Reddy (2016: 1321) contend that at least two light sources are required to avoid strong shadows. For the best balance, at least three sources of light should be available in every space including sunlight. Dimmers can change the balance between artificial light with natural light in the day (Better Homes and Gardens 2020: 3).

The opinion of head chefs reflected that 88.2 % (Figure 10.4) of kitchens had work areas free from shadows. As lighting usually comes from fittings anchored in the ceiling, light is compromised by shadows created by equipment or partitions (Turner 2008: 1). As per Die-Pat (2016b: 2), any suspended light fittings will collect dust and represent a potential source for food contamination. The researcher's approximation revealed that only 6.75 kitchens were unsatisfactory and 50 % rated well without shadows (Figure 10.5). However, head chefs felt that almost 90.9 % of the kitchens were free from shadows. Questionnaire responses from kitchen managers and head chefs indicate confidence that workers do not have complaints about glare and contrast (Figure 10.3).

10.5.3 Eyestrain

As documented in Hima Bindu and Reddy (2016: 1321), 62.2 % of cooks work with insufficient lighting levels, a situation that initiates eyestrain and eye irritation that affect well-being of kitchen workers. Figure 10.2 indicates that local lighting was provided to 32.2 % of workers for close work in the kitchen to reduce eyestrain and fatigue. Whereas only 73 % of workers felt the visual comfort at their workplace was satisfactory and is free from glare, reflections, contrast, a higher 93.9 % of the kitchen managers believed that employees could comfortably see their work without straining their eyes. This gap is likely to account for reduced well-being among workers, for example, per Wiholm *et al.* (2007: 54) find that eyestrain is accompanied by shoulder-neck symptoms. Good lighting can decrease eyestrain and the headaches, nausea and neck pain which often accompany eyestrain (Unicamp 2016: 1). Disturbance from flickering lights (Table 10.11 page 284) can cause eyestrain (Boduch and Fincher 2009: 4). Headaches are common, particularly if the fluorescent lights flicker (Blink Eye Care 2017: 1). Almost 95 % of kitchens used fluorescent lights in the common zones to include all areas except in pick-up sections and canopy hoods.

10.5.4 Flicker

The extent of eyestrain discussed in 6.4.2, depends on whether a light source is steady or flickering, as flickering light tends to create eyestrain. Using exploratory factor analysis, component 1, Brightness revealed a factor loading of 0.613 for the presence of flickering lights (Table 10.12 page 286). Knez (2001: 1) points out that the luminous flicker produced by fluorescent lighting leads to visual discomfort, deteriorations in visual performance, stress and headache which, have a detrimental impact on task performance.

Table 10.10 Presence of flicker in kitchens

Estimation		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	2	1.17	1.3	1.3
	No	150	88.23	89.55	100.0
	Total	152	89.4	100.0	
Missing	System	19	11.1		
Total		170	100.0		

Of the observed kitchens, 72.7 % of kitchens had no flickering light. The chi-square values were 55.143 with p=0.000 flickering lights in the kitchens. Additionally, the interviews reveal that less than 2 % of kitchen workers perceive flickering lights in their kitchens (Table 10.10).

Data on LED flicker is not available as none of the kitchens in the primary study had LED lighting. Most people can see the flicker in fluorescent lights that have a flicker rate of 50 cycles per second (or 50 Hz) (Canadian Centre for Occupational Health and Safety 2018: 1). Flicker with LED lights may be more noticeable as LED lights flicker between less than 10% and 100%, whereas fluorescent lights dim to about 35% and back to 100% (Government of Canada 1978-2018). Any reduction in flicker according to Fostervold and Nersveen (2008: 175) can lead to reduced job stress severity.

A minority of below 2 % of kitchen workers responded that flickering lights exist in one kitchen which shows that flicker may not be a common feature in commercial kitchens. The researcher approximated that 85.7 % of the kitchens had no flicker, however, 3.6 % had unsatisfactory lights with flicker. Interestingly, Fleming (2003: 127) claims women and those aged less than 30 years most frequently perceive flicker. Almost 56 % of the kitchen workers of the sample kitchen workers fell into this group. Low-frequency ballasts lighting, as well as old bulbs, tend to flicker at lamp ends due to malfunction or aging of globes.

Exploratory factor analysis (Table 10.12 page 286) revealed a factor loading of 0.818 and 0.613 for the presence of natural light and flickering lights, respectively and, was categorised into component 1, Brightness. Slightly over twenty-one percent (21.2 %) of the kitchens had unsatisfactory natural light. Almost seventy-three percent (72.7%) of kitchens had no flickering lights, only one (3.0%) kitchen had flickering light. Unfortunately, responses from five kitchens on flicker are blank. About 19 kitchen workers were not sure about flicker. Similarly, 158 workers had no clue about disturbance from flicker and illustrated in Appendix 22 as missing data. The chi-square values were 3.966 and 55.143 with p=0.265 and p=0.000 respectively for natural light in the kitchen and flickering lights.

10.5.5 Glare and contrast

Kitchen areas should be as free from glare and unwanted reflections as practicable. Reflections and glare can cause reduced visibility and become a source of distraction and annoyance (Dudeja ***et** al*. 2016: 366). The presence of contrast and glare were not common in most of the kitchens investigated. Contrast and glare were controlled, as was borne out in less than 4 % of the kitchens exhibiting such spots mainly due to shine from new equipment (Table 10.11). The controlled contrast and glare in the study sample can reduce discomfort glare observed by Lorentz (2011: 86) that resulted in headaches, eye fatigue and other eye discomforts over a prolonged period. The current study found that p-value was .739 with significance level of 0.001 and chi-square statistic of 66, for correlation between the staff complaints about contrast in kitchen and staff complain about glare in the kitchen (Figure 10.3).

10.5.5.1 Glare

Glare by its definition is brightness within the field of vision that reduces the visibility of an object and arises commonly from non-compliant lighting installations (EE IIT 2013: 3); and must be minimal in a kitchen (Hima Bindu and Reddy 2016: 1321). A minimum of two lamps of 300 lux is required to avoid glare and strong shadows (Balogh 2008: 61). Almost 88 % of head chefs in the present study were confident about the absence of glare in kitchens (Table 10.11).

Table 10.11 Staff complain about glare

Estimation		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Never	29	87.8	87.8	87.8
	Rarely	2	5.9	5.9	93.7
	Fairly Often	1	2.9	2.9	96.6
	Very Often	1	2.9	2.9	100.0
	Total	33	100.0	100.0	

The researcher submits that the glare in the kitchen is experienced when lamps, windows, luminaries, other areas are brighter than general brightness in the environment. It was also noted that in one of the kitchens in the present study, skylights were white-washed to prevent glare. One kitchen exhibited a discernible direct glare as all the equipment was new and shining, while two other kitchens presented indirect glare (Appendix 23). Direct glare results from bright luminaire in the field of vision. EE IIT (2013: 2) posits that direct glare, minimisation or avoidance is possible by mounting luminaries well above the line of vision or field of vision and limit both brightness and light flux in the normal field of view. Appropriate balanced lighting is the most essential factor in designing for glare-free environments (Osterhaus 2009: 1). Figure 10.5 indicates that only two kitchens or 6.7 % of kitchens had indirect glare as estimated by the researcher.

Over the summer data collection, glare occurred in two kitchens from sunlight reflection on shiny surfaces (Figure 10.3). The bright shiny kitchen surfaces require that the placement of windows and skylights be carefully considered, as they can also inadvertently become a source of glare (Dudeja *et al*. 366). Further to sunshine, five kitchens had the countertops that reflect bright light off the surfaces. The observational study (Figure 10.3) further revealed that 3.8 % and 6.7 % of kitchens had direct glare and indirect glare with chi-squared values of 23.154 and 11.667 respectively. Since p= 0.000 and 0.020; less than the significance level of 0.05, this is strong evidence to conclude that the variables: glare and brightness are associated. Triangulation of data from the three instrument reinforces the validity of data obtained from each.

The opinion of head chefs elicited on 'the staff complain about glare in the kitchen' (Figure 10.4) denotes that glare controlled, as less than 4 % of kitchens had spots attributable to shine from new equipment. According to Table 10.12 (page 286), 85.3 % of the staff did not complain about glare in their kitchens with p=0.000 and chi-square statistic of 66, expressing strong evidence to conclude that the variables: presence of glare in kitchen and complaints about glare are associated. There were insignificant correlation values for items related to the negative effect of glare, a deduction evidenced by 93.9 % of the kitchen managers (Table 10.5 page 274) indicating that employees can comfortably see their work without straining their eyes. Additionally, 73 % of the workers felt that the visual comfort at the workplace was satisfactorily free from glare. The latter corroborated in the kitchen worker interviews (Figure 10.4) where only two (1.2 %) kitchen workers complained about glare.

The siting of glare in component 1, Brightness appears to be underpinned by literature that considers glare to be substantial for its potential to hinder visual comfort as it contributes to visual annoyance (Hwang and Kim 2012: 86). Hence, Leech *et al.* (2002: 427) assert that glare reduces the ability to see objects or details clearly. On the other hand, the more intense the task, the brighter the light required (Boduch and Fincher 2009: 4). Consequently, van Den Wymelenberg and Inanici (2014: 145) emphasise the need to investigate daylight; artificial lighting, glare and visual comfort together to get a more holistic picture. Such an investigation is, however, beyond the scope of the present study.

Various suggestions have been advanced to manage glare. Simply dimming of bright light suggested by Woofter (2014: 1) to improve lighting comfort is not feasible in commercial kitchens. More feasible is the suggestion of Morton (2016: 18) that glare from inappropriate lighting be reduced with light from multiple sources. Hence, Ring (2018: 22) adds that if the light from the light source spreads out in the room, glare is negated. Identification of the exact number depends on the size and shape of the kitchen (Balogh 2008: 61).

Table 10.12 Rotated Component Matrix: researcher's opinion on lighting ergonomics

	Component	
	1 Brightness	2 Luminance
25. Presence of Natural light	0.818	0.205
26. Presence of skylight	0.337	0.268
27. Sufficient shielded lights to prevent shadows/dark areas	0.607	0.701
28. Presence of direct glare	0.827	-0.278
30. Presence of flickering lights	0.613	0.274
31. Presence of Contrast in kitchen	-0.039	0.934
Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.		
a. Rotation converged in 3 iterations.		

Using exploratory factor analysis (Table 10.12) reveals a factor loading of 0.827 for direct glare and categorised into component 1, Brightness. The questionnaire further revealed that although 76.5 % of the head chefs claimed that their staff are happy about adequate light-illuminance in kitchens, 8.8% of the staff complained about glare. The presence of direct glare was only observed in one kitchen. Using exploratory factor analysis (Table 10.13 page 287) a factor loading of 0.851 and 0.801 for complain about glare, contrast and categorised into component 1, Visual Discomfort. For the correlation between the staff, complaints about contrast in kitchens and staff complain about glare in the kitchens, a p-value of 0.739* with a significance level of 0.001 were ascertained. About sixty-one percent (60.6 %) of the kitchens had no direct glare; only 3 % had direct glare.

10.5.5.1 Contrast

Contrast when subjected to exploratory factor analysis, revealed a factor loading of 0.801 and was categorised into component 1, Visual Discomfort (Table 10.14 page 288) as mentioned above. Table 10.12 indicates that 87.8 % of head chefs believed that kitchens staff had no complaints about contrast. The questionnaire further revealed on item: the staff are happy about adequate lighting categorised into component 4, Fitting Illuminance with a factor loading of 0.800. The researcher's approximation indicated that none of the workers had any complaints about contrast (Figure 10.5).

Table 10.13 Rotated Component Matrix: chefs' opinion on lighting ergonomics

	Component			
	1 **Visual Discomfort**	2	3 **Conservation**	4 **Fitting Illuminance**
1 All the kitchen equipment is in good repair	-0.120	-0.213	0.875	0.006
2 The amount of light in your kitchen is adequate	-0.152	0.204	0.752	0.080
3. The staff are happy about adequate lighting in kitchen	-0.061	0.208	0.047	0.800
4 The staff complain about glare (difficulty seeing in the presence of bright light such as direct or reflected sunlight) in the kitchen	0.851	-0.046	-0.050	0.073
5 The staff complain about contrast (the difference in brightness or colour that makes an object clear) in kitchen	0.801	0.257	-0.147	-0.192
6. All kitchen equipment is installed as per specification	-0.160	-0.057	0.693	0.134
Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.				
a. Rotation converged in 5 iterations.				

Interviews revealed that 1.8 % of the staff complained that visual comfort was not good in their kitchens' work areas (Figure 10.2). The observational study further revealed that 9.1 % of the kitchens had contrast with chi-squared values of 66. Since p= 0.000; less than the significance level of 0.05, this is strong evidence to conclude that the variables contrast in kitchens and areas free from shadows are associated. Staff are happy about lighting in kitchen with p= -0.480 with significance level of 0.004. Common magnitudes in the social sciences are low to moderate communalities of .40 to .70 (Costello and Osborne 2005: 4). The fewer the staff complaint about light contrast in the kitchen, the higher the incidence of adequate lighting in kitchens with staff being happy about it.

Table 10.14 Staff complain about contrast

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Never	29	87.8	87.8	87.8
	Rarely	2	6.06	6.06	93.8
	Fairly Often	1	3.03	3.03	96.83
	Very Often	1	3.03	3.03	100.0
	Total	33	100.0	100.0	

All kitchens in the study used artificial lights during the day (Figure 10.1 page 268). According to Morton (2016: 18) inappropriate lighting contributes to low or high contrasts. The greater the contrast, the easier the comprehension. The use of black text on white paper effectively supports the principle.

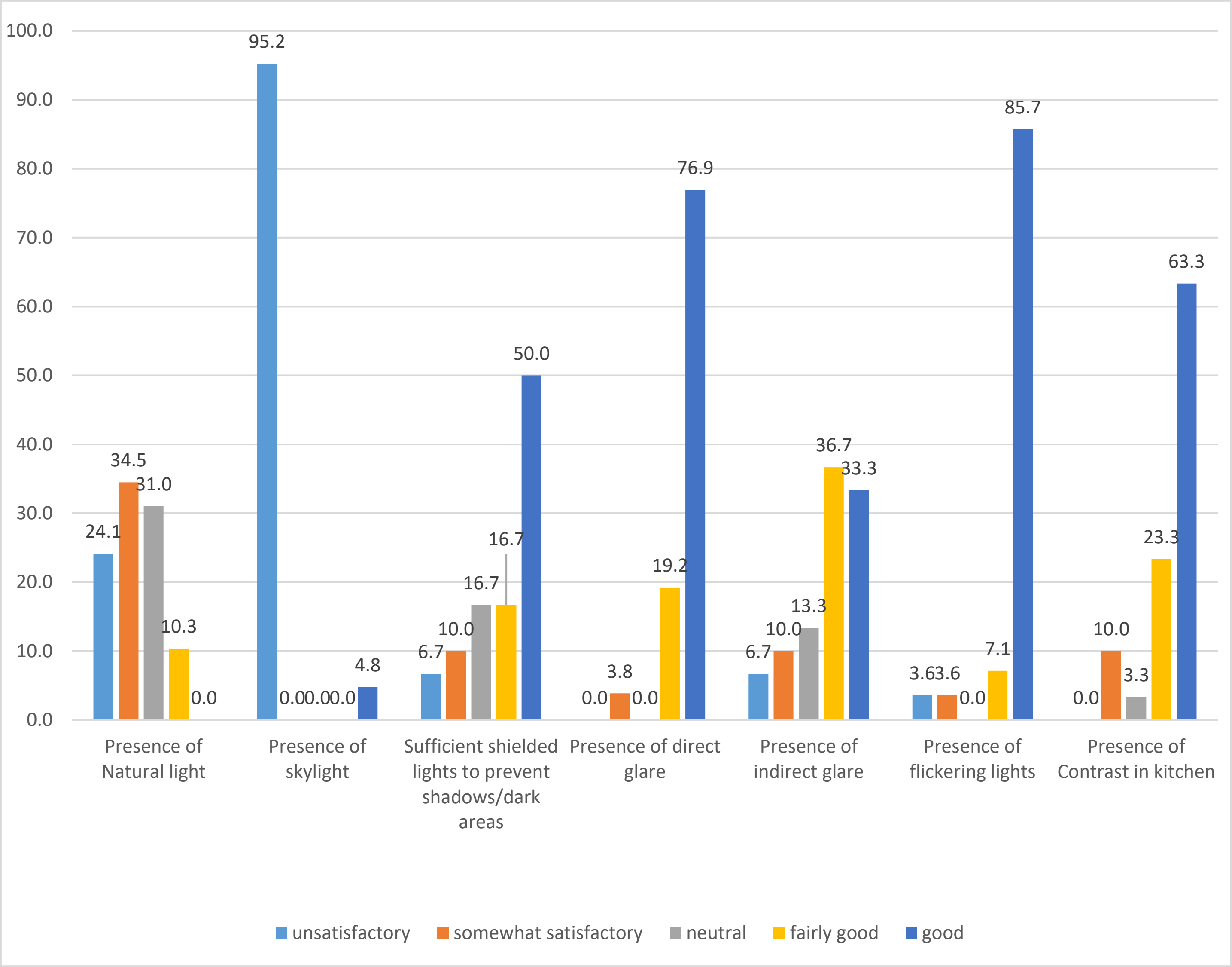


Figure 10.5 Researcher observation of kitchen lighting

The desired light levels for different types of use, contrast ratios of 1:3 to 1:10 foster concentration but still allow acuity of surrounding items (Woofter 2014: 1). The location of contrast in the component 1, Visual Discomfort in the present study appears to be underpinned by the work of Boduch and Fincher (2009: 4) who consider the substantive place of contrast to potentially hinder visual comfort as it contributes to visual annoyance.

The researcher's subjective evaluation revealed that kitchen workers views are similar on lighting. Only objective evaluation of sampled kitchens indicated the accurate state of lighting conditions.

Table 10.15 Contrast in kitchens

	Tests of Between-Subjects Effects					
Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
	Adequate lighting (lux) on food preparation areas	7.5	2	3.75	9.375	0.02
	Adequate lighting (lux) on cooking areas	11.3	2	5.65	7.635	0.03

AB31=Presence of Contrast in kitchen

Using exploratory factor analysis, contrast (Table 10.12 page 286) revealed a factor loading of 0.934 and was categorised into component 2, Luminance. Keeping with the claim that staff are happy about adequate light with component 4, Fitting Illuminance in kitchens with a factor loading of 0.800, 9.1% of the kitchens had slight contrast in some areas, although 76.5 % of the head chefs (Figure 10.5) agree with it. Staff complained about contrast in kitchen and this has a negative correlation with p = -0.480 with component inadequate lighting in kitchen; with significance level of 0.004. Staff are happy about lighting in kitchen with p= -0.480 with significance level of 0.004. Thus, the fewer the staff members who complained about lighting contrast in kitchen, the higher the incidence of adequate lighting in kitchens and staff being happy with it.

According to HSG38 (1997:13), strong shadows on the task area or reduced contrast of task can be solved by providing local or task lighting. Sometimes when tasks are difficult to see, increasing contrast between the task and the background is recommended. Since p= 0.02 and 0.03; less than the significance level of 0.05, this is strong evidence to conclude that the variable contrast and lighting in preparation and cooking areas are closely associated.

Clearly, adequate lighting in preparation and cooking areas affects the degree and presence of contrast in kitchens (Table 10.15). While proper lighting in the cooking areas can speed up work and raise accuracy, deficient lighting can make cooking troublesome and raise the probability of accidents. The association of the variables in Table 10.12 will accordingly assist in formulating indoor environmental criteria for design of restaurant kitchens in Durban in respect of lighting. It has a predictive quality to achieve Objective 1 and Objective 4.

10.6 Lighting maintenance plans

Lighting hazards in the workplace, which can affect the health and safety of people include improper lighting installation and maintenance. According to HSG38 (1997: 4), lighting maintenance should coincide with general maintenance so that it does not interfere with work activities.

10.6.1 Maintenance of lighting

All the kitchens in the present study followed corrective maintenance where light bulbs and fixtures are repaired or replaced after wear, malfunction or break down. The correlation between lights clean and adequate lighting on cooking areas was found to be statistically significant, r (30) = + 0.592, p=.001. Preventive or scheduled maintenance, where equipment or facilities are inspected, maintained and protected before breaking down is endorsed by the researcher for maintenance of brightness of lights to circumvent low lighting levels due to dullness of bulbs in kitchens.

Using exploratory factor analysis (Table 10.13 page 287), maintenance revealed a factor loading of 0.752 and was categorised into component 3, Conservation. The opinions of head chefs denote that 73.5 % of kitchens had adequate light (Figure 10.2). Only one kitchen had drastic low lighting keeping in tune with the theme of the restaurant. The p-value was .595* for correlation between the amount of light in kitchen is considered by the researcher to be adequate and all kitchen equipment is in good repair with significance level of 0.001. There was also a positive correlation between adequate light in kitchen and all the equipment is in good repair with a p-value =0.595 and a chi-squared value of 33.52 and p=0.000. Whereas over 87 % of the respondents claimed that there was no problem with lighting, 12 % believed that changing globes to solve the problem of lighting (Figure 10.6).

Food service workers believed that maintenance of lighting was adequate. According to Standard (2019:1), lighting fixtures must be resistant to a variety of conditions such as escaping steam, smoke plumes, grease and food splatter. All lighting in food preparation areas, dishwashing areas, food and food equipment storage areas and food display areas must be shielded to protect them from shattering and protect food and equipment from broken glass (Manitoba 2016: 10).

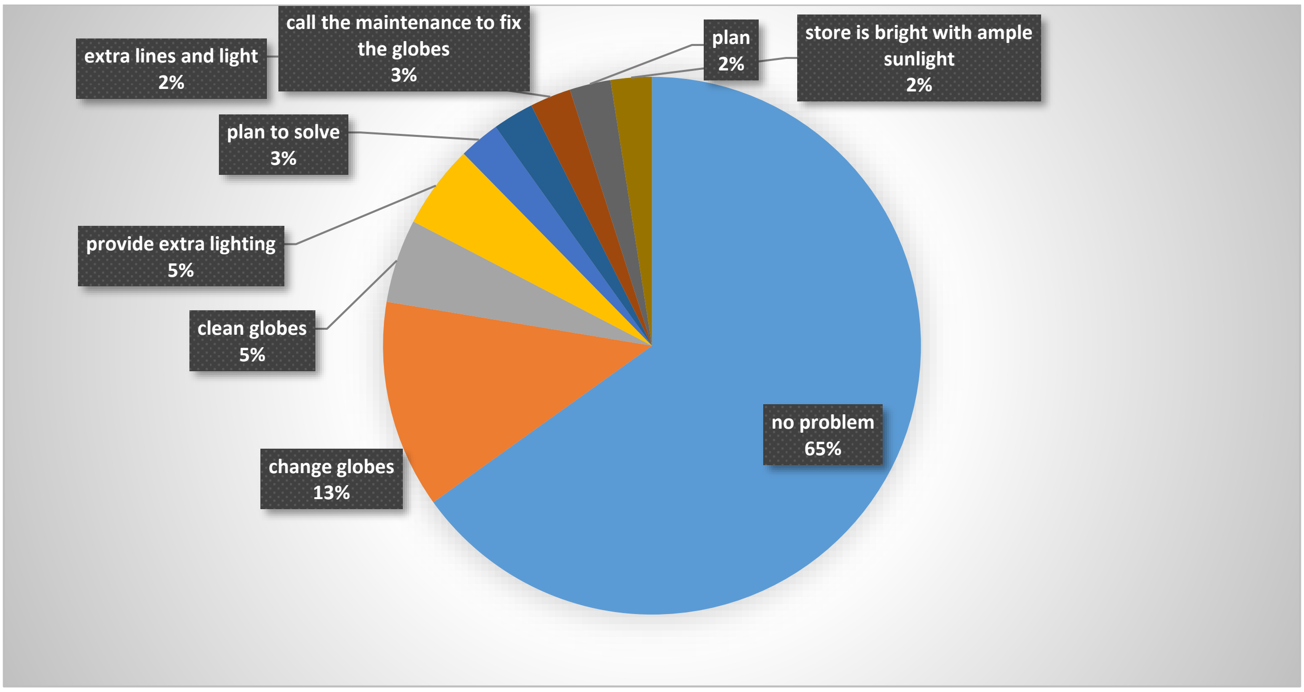


Figure 10.6 Options to solve problems of kitchen lighting

Light bulbs can be a source of injury in a commercial kitchen fire. As temperatures rise, bulbs can explode, sending fragments flying at high velocity and workers can be in danger of being injured by these high-velocity shards. This hazard can be eliminated by covering light bulbs near cooking equipment with explosion-resistant covers; an easy way to help prevent serious injury during a fire (Atlantic Training 2015: 1). Maintenance plans were adequate but need further improvement to improve vision for older staff and provide local/task lighting in specific work areas. Figure 10.3 indicates that 95 % of the staff agreed that regular maintenance of lighting takes place in their kitchens.

Best practices advocated from the hospitality industry on lighting include several factors. Green Hotelier (2010: 1) suggests the replacement of old fluorescent tubes as 20 % deterioration in performance is possible over three years, with the T8 models if possible. A “tri-phosphor” coating will reduce energy consumption by 10 % and improve the quality of lighting over its lifespan. However, Ballast Shop (2020: 1) recommends T5 lamps, which are 40 % smaller than T8 fixtures but providing more light. Replace tungsten bulbs with CFLs to reduce consumption by up to 80 % and they last up to 10 times longer and use 75 % less energy (Statmats Communication,Inc 2020: 1). According to Mignanelli (2015: 43), properly designed diffusers should be installed to assist with even distribution of light and contain fragments in the event of a globe shattering. The illuminance level made at least 100 lux higher than the recommended level, because of a light loss factor that occurs over time.

10.7 Conclusion

The chapter began with lighting levels in kitchen, natural and artificial lighting, and effective lighting in work areas. Thereafter, correlation in lighting areas and correlation for headache was expressed. The data obtained from the three instruments indicate that the lighting levels in kitchens comply with SABS and OHS Act requirements. However, other International Standards CIBSE, WHO and OSHA recommend higher lighting levels in different kitchen areas for better visual comfort. Sampled staff are unaware of brightness of light, and task lighting is not a common feature in commercial kitchens. Age is an important factor in adaptation to light, however, additional lighting was not provided for elderly staff. Although familiar with the presence of contrast and glare, the kitchen workers were unacquainted with the occurrence of flicker. The next chapter will proceed to a summary of the study and recommendations.

CHAPTER ELEVEN

CONCLUSION AND RECOMMENDATIONS

11.1 Introduction

In the previous chapters, revelations from data were analysed and discussed. This final chapter will set out to summarise the main findings, provide absolute deductions based on the analysis and interpretation of the data and suggest a way forward on how the study objectives in the commercial kitchen environment may be addressed. Although this study was restricted to Durban, South Africa, the findings are of general importance in all countries with similar climatic conditions. The first part of this chapter will review the theoretical and empirical investigations, followed by discussions pertaining to the achievement of the research objectives. The chapter will conclude with recommendations deduced and opportunities for further research.

11.2 Summary of the theoretical alignment

This study set out to investigate the impact of heating, lighting, acoustics, ventilation and humidity on the indoor environmental quality and the well-being of food production workers. The summary that follows will clarify the alignment of the primary study with prevailing theory.

11.2.1 Heat

i. The general evaluation criteria for thermal comfort often used in other work areas, for example, the adoption of Fanger's standard Predicted means vote/Predicted percentage dissatisfied (PMV/PPD) index common to office environments cannot be applied in commercial kitchens. The heat adaptive model (HAM) was adopted in the study because a functional commercial kitchen comprises combinations of high activity levels, high air temperatures and high radiant temperatures that render Fanger's standard unsuitable for application in commercial kitchens.

The sections 2.10, 7.2, 7.3 and 7.7 collectively affirmed that thermal comfort is predicated by individual factors comprising age, gender, wet bulb globe temperature, fitness, acclimatisation and ethnicity and the type and scope of kitchen activities. The latter comprises cuisine, style of service, the volume of meals prepared, number of plated meals and peak activity time.

ii. The theory posits that range, type and size of cooking equipment affects the heat generated in the kitchen. Section 7.4.4.2 revealed that extra-heavy-duty equipment cooks at a higher temperature and produces radiant heat as experienced by workers near traditional kilns and tandoors.

iii. In summer months, heat and humidity according to theory, are severe in kitchens without air conditioning or vents in the kitchen. In this regard, section 7.6.3.1 and Figure 7.9 revealed that the minimum and maximum discomfort indices indicated that staff in Durban kitchens are uncomfortable during peak periods of business. Higher levels of humidity especially during peak periods raised kitchen temperatures.

11.2.2 Ventilation and humidity

i. The flow of fresh air is undisputedly a feature of good ventilation. Consistent with theory, and further to kitchen location, kitchen airflow in this study was mediated by combinations of open back doors, open windows, open front doors, hatches, fans, air coolers, air conditioners, whirlybirds, chimneys and extraction systems. However, these have limited ability to remove kitchen heat and fumes, especially in urban areas as observed in section 3.4. Natural ventilation is further, beset by challenges such as the irregularity of airflow due to the wind forces being either unreliable or inadequate. Nonetheless, coastal Durban has reasonable airflow that could be harnessed in the kitchens. The wind power potential in the general Durban region is considered moderate.

ii. Kitchen airflow was facilitated by mechanical means and fenestration design. Theory points to airflow slower than 0.5 m/s as pleasant and is comfortable at an airspeed of about 0.25 m/s. In this regard, 12 % of the kitchens that had no airflow at all in some work areas are unsatisfactory. Prior empirical studies indicate that indoor air distribution determines indoor air quality and human comfort.

iii. Airflow into kitchens was assisted by openings along with open-plan design that maximises cross ventilation. High ceilings and large corridors in kitchens facilitated air movement. Closed doors obstruct kitchen airflow whereas natural ventilation was improved by open windows. Fans and whirlybirds assist with natural ventilation. Air curtains according to theory are beneficial in kitchens, air vents and air-conditioned cool air help to mitigate staff discomfort from heat and humidity.

iv. Authoritative literature points to the influence of design in respect of kitchen area and volume, the number of diners, volume of food cooked, cuisine, air infiltration and density of workers in the kitchen on airflow; features equally reflected in the present study. The measures of the staff space ratio were prominent for its variation from 2.67 to 21.23.

v. The type of cooking equipment, ingredients, recipes and procedures, fuel types, temperature and ventilation equipment used are cited in theory to affect the extent and composition of emissions generated during the cooking process. This study confirmed that the widespread use of gas and electricity generates higher emissions of CO_2.

vi. Along with fumes and moisture, the measures of CO_2 had mean values within 1000 ppm, although the values ranged from 403 ppm to 2155 ppm. The measure of CO_2 concentrations according to the literature is a primary indicator of air quality and inadequate ventilation leads to elevated CO_2 levels. Beyond the visibly higher levels of smoke and fumes during peak period, CO_2 concentration was substantially higher (>1000 ppm) from the use of gas flame grillers and tandoors.

vii. There is conclusive evidence from the theory that fuel and equipment used for cooking affect the humidity in the kitchen. Humidity in commercial kitchens in Durban was also influenced by climatic conditions with higher RH levels near cooking and dishwashing areas. More than 10 % of kitchen managers felt that Durban kitchens were humid and 15 % felt that it was sweaty in the kitchen.

viii. Thermal perception is the temperature as "felt" by the body of workers was affected by humidity levels. According to the theory and section 7.6.4 and Table 7.27 (page 183), the food service workers exhibited symptoms of heat stress and heat strain such as tiredness and intense thirst with 23.5 % demonstrating a decrease in attention and or irritability.

ix. Section 8.4 affirmed the need for attention to the design and location of exhaust hoods for effective kitchen ventilation. Humidity and temperature according to theory increase if the hoods were not able to capture all the thermal plumes. Also foul air extraction was found to benefit during expelling of thermal plumes and can prevent mould growth. Incorrect specifications of extraction systems reduce tolerable levels of fumes, grease and moisture. Some of the overhangs were extremely small (0.06 m) due to the Chinese design as observed in section 8.4.2; the size of the extractors seemed to be inadequate (2.10 m) in two kitchens, as cooking equipment extended beyond the hood length. A hood overhang of 0.1 m is a requirement in Chinese kitchens.

x. Good maintenance standards and procedures are a pivotal requirement for better ventilation and humidity management in the kitchens. This theoretical imperative was demonstrated in sections 8.5.6 and 8.7.1, establishing that ventilation was insufficient to maintain optimal humidity levels and good air quality due to an inverse relationship between maintenance and air quality.

xi. Section 3.3 confirmed that people felt comfortable at an airspeed of about 0.25 m/s or 15 m/min and that airflow slower than 0.5 m/s felt pleasant. Airspeeds less than approximately 0.1

m/s as conveyed in literature, will usually cause a sensation of staleness and stuffiness, even at relatively low temperatures. The findings in section 8.3 similarly recorded that 56 % of the workers complained that ventilation was inadequate in the kitchens and the mean airflow rates in the dishwashing and the oven areas were particularly low. Prior theory recommends airspeed of 1.2 m/s at 30° C with a relative humidity of 80 %.

xii Durban with a subtropical climate is known for high humidity levels causing discomfort. The relative humidity levels in the kitchens ranged from 32 % to 74.4 %; the high value was due to rain during the field study. The maximum relative humidity values exceeded 60 % and were as high as 89.5 % near ovens. Staff complained about humidity such as sweat not drying (30.3 %), uniform being wet (12.1 %) and stickiness (6.0 %).

11.2.3 Noise

i. The literature contends that noise is generated from food preparation and cooking with food service equipment added to the noise in the kitchen. The findings in sections 9.2.3 and 9.3.1 established that average noise levels across cooking areas ranged from 70 dBA to 80 dBA and while kitchen workers are vulnerable to these noise exposures, they accept it as part of occupational risk.

ii. The literature, as expected, attributes noise and poor acoustics to hinder communication. Section 9.3.3 confirmed that kitchen workers found difficulty communicating with other kitchen workers. This situation as described in prior studies could have been exacerbated by noise-induced hearing loss, however, not present in the sampled kitchens.

iii. Among the kitchen workers, the theory points to dishwashing staff at risk for overexposure to noise. Ware washers have the highest exposures to noise in this work environment. Section 9.2.3 attested that 33.3 % of the kitchen personnel were dissatisfied with the noise from dishwashers with a mean noise level of 76.35 dBA.

iv. Extractors according to the literature, produce continuous noise during operation in the kitchen. Section 9.3 confirmed that in catering enterprises kitchen staff were exposed to noise from different sources including the extractors with noise levels ranging from 70 dBA to 83 dBA. Improved maintenance of HVAC can reduce noise in kitchens.

v. The result in Section 9.5.1 indicates that more than 70 % of kitchens had a weekly maintenance program of equipment that helps to lower noise levels in kitchens. Preventative maintenance in theory prevents breakdowns and ensures that equipment is 99 % operational and safe to use.

vi. Age according to the literature, associated with hearing loss and NIHL is prevalent most among individuals over the age of 65. Section 4.6.1 indicated that among personal factors, age is the most important factor in adaptation to noise.

11.2.4 Lighting

i. Bright and direct lighting according to theory is required in all food preparation, cooking and dishwashing areas. Workers were found to be more alert, less fatigued and more energetic in the bright light conditions as it decreases sleepiness and improves psychomotor vigilance performance. The complete disparity in Section 10.2, indicates that some kitchens did not have adequate lighting levels, and it affected workers who strained to work and sometimes even developed headaches.

ii. Organisations lack training in ergonomics which according to theory, benefits workers. The importance of the qualitative nature of lighting such as contrast, glare and colour, in relation to kitchen work was frequently not sufficiently appreciated. Most kitchen staff are unaware of good lighting even though insufficient lighting can cause eyestrain and headaches among workers. Section 10.5 affirm that 68 % of the kitchens had unsatisfactory task lighting and contrast, glare and flicker are controlled.

iii. The literature contends that older workers have higher lighting needs. An average 60-year-old person's eye requires three times more illuminance than an average 20-year-old person's eye. Complaints of inadequate lighting over the kitchen work surfaces are common among elderly people. Section 10.4.3 disclosed that 76 % of the workers felt that the lighting needs of older workers were met, although the older staff complained about visual discomfort.

iv. However, Section 10.6.1 revealed that food service workers believed that maintenance of lighting was followed adequately. Improper lighting installation and the adequacy of lighting maintenance in the workplace was shown in literature to affect the health and safety of people.

11.3 Summary of the empirical study

An empirical study by definition is the collection and analysis of primary data based on direct observation or experiences in the field. It is a way of gaining knowledge by means of direct and indirect observation or experience (Anguera *et al*. 2018: 1). The empirical evidence will be summarised in this section. The quality of the data as elucidated in sections 6.4.2.9, 6.4 and 6.7 in the Methodology chapter confirm that the quantitative and qualitative measures have been met to validate the quality of the study. The triangulation of the various data collection techniques and statistical data analysis offered ample evidence of the accuracy of the data collected.

11.3.1 Heat

i. More than 98 % of kitchen workers prefer Durban weather and feel comfortable in its subtropical coastal climate. Notwithstanding, a high discomfort index mean values of 100 to 105 from the heat were observed in most kitchens. The discomfort index values for dishwashing areas (98) are lower than cooking areas (103) due to the absence of radiant heat. During summer, heat and humidity are severe in nine kitchens as no cold air is pumped into kitchens without air-conditioner or vents. Of these, five kitchens use whirlybird installations to reduce the heat load in the kitchens.

ii. The heat from ovens and dishwashers contribute to the increase in temperature in the kitchen along with the heat from the stoves p=0.011 and 0.015. The relationships with air-conditioners (p=0.00) and domestic fans (p=0.031) indicate that the greater the number of cooling equipment, the lower the heat experienced near stoves. There is strong evidence to conclude that the variables are negatively associated. The most common physical symptom of heat in kitchens is heavy sweating with p=.003. Psychological symptoms displayed included use of foul language and since p=.008, strong evidence to conclude that the variables are associated.

iii. The kitchen staff socio-economic status was declared by head chefs to contain factors influencing their ability to cope with kitchen heat, to include work experience (47 %), age (35 %), and correct body weight (14.7 %). With respect to demography, race (37.5 %) and fitness (70 %) were advanced as mediating factors in coping with heat, 20.6 % accepting fitness as the highest level of influence on coping with kitchen heat. Exploratory factor analysis further revealed a factor loading of 0.780, 0.850 and 0.554 for gender, race and fitness, respectively, among factors influencing coping with kitchen heat.

iv. As anticipated, cooking emerged as the primary and highest generator of kitchen temperature. Sections 2.11 and 7.4 established that thermal strain on workers in commercial kitchens across load spectrums, with the preparation cook or line cook in section 7.2.7 encountering extreme heat. A noteworthy feature in the sample is that a particular menu does not need the presence of stoves in kitchens as the cooking method has changed. Light-duty load appliances such as pizza conveyor ovens in pizzerias were used to prepare pizzas without utilising any other cooking equipment; conventional stoves were lacking in these kitchens.

v. A range of factors affected the heat experienced by kitchen workers particularly those near stoves. The primary factors revealed in the statistical analysis were kitchen height, symptoms red face and sweating, discomfort index, space ratio and state of the uniform. The grillers and bakers of the kitchen brigade are particularly heat exposed.

vi. 'A regression model' showed that the equation for dependent variables titled secondary factors affecting heat near stoves helps to compose indoor environmental criteria for the design of restaurant kitchens. The implications from the model proved that these variables are strongly associated $p=0.039$ for job position; $p=0.045$ for years of employment; $p=0.024$ for worker shift, and $p=0.012$ for type of kitchen. One of the best fitting linear regression model for predicting heat near stoves is a linear combination of type of kitchen, job position, years of employment and worker shift. For every unit increase in heat near stoves, a 2.013 unit increase in discomfort index value was predicted, holding all other variables constant.

v. The preparation zone of kitchens practising oriental cuisine was recorded as having the highest temperature of 31.85° C, which was attributable to the high wok cooking temperature. Also, Italian cuisine kitchens have brick kilns that increase operative temperature near wood-fired ovens to a mean of 31.4° C.

vi. All the areas in the cooking zone in food service operations, particularly in extra heavy-duty load kitchens, had temperature ranges from 30.66° C to 32.20° C (fryers) in the study. Grillers experienced higher mean temperatures of 33.75° C and 97.1 % of the workers in this group were reported as stove exposed. Almost 70 % of the kitchen workers claimed that food preparation produces heat with a high temperature of 31.85° C, and kitchens are hot.

vii. Seventy-five percent (75 %) of the kitchen workers claimed that the kitchens were extremely hot during maximum kitchen capacity utilisation. Almost 41 % of kitchen staff found the thermal environment uncomfortable. Measures of humid areas indicate that it is uncomfortable near stoves and dishwashers. More than 15% of chefs on duty were observed to be red-faced. Another model for predicting heat near the stove is a linear combination of symptoms of face is red among kitchen workers and discomfort index (heat from stove or oven). Another stepwise regression model for predicting heat near the stove is a linear combination of South African Indian, South Africa African, area of the kitchen, output in the number of meals per day and other cuisines.

viii. The best fitting linear regression model for space and heat experience indicated that for every unit increase in area, a 1.3 unit decrease in heat experience near stoves area is predicted, holding all other variables constant, provided this increase in space be not occupied and permits air movement to dissipate heat. Considerably more head chefs and kitchen managers (86.7 %) indicated that the kitchen area was less than 100 m^2 ($p < 0.001$).

ix. Factors involving genotypic and phenotypic heat response characteristics among kitchen workers include shape of nose, skin colour and type of hair. Almost 89 % of kitchen workers were Africans with funnel noses (64.4 %).

x. Medium-brown skin tone was most frequently observed among kitchen workers (54.7 %) belonging to African and Indian races. However, no relationship was found between skin colour and heat tolerance. Almost 48 % of African workers had dreadlocks, hair extensions and hair weave; elaborate synthetic hairstyles were observed among 28 %. Phenotype feature includes body stature. Almost 65 % of men had mesomorphic body type whereas 55% of women had endomorph body type. Heat tolerance was affected by body mass index and not absolute body shape.

Against the raised thermal conditions in the kitchen, worker discomfort from excess hair was indicated in 64.2 % of respondents. In this regard, 76.5 % perceived and that being shaven would be more comfortable working in the kitchen.

xi. The correlation $p=0.000$ is significant between the kitchen worker's uniform and the number of meals cooked per shift. A chef's uniform can prevent heat dissipation. The greater the meal output, the greater the discomfort from workers' uniforms.

xii. A strong correlation was indicated with $p=0.040$, significant between kitchen worker's perception of ventilation in their work kitchen either inadequate or satisfactory and using an air-conditioner in their residence. The use of an air-conditioner at home after work is likely to help staff to cool off and come to work well-rested.

xiii. Sweating is a common response to thermal discomfort along with kitchen workers' tiredness and intense thirst. Several kitchen workers (23.5 %) were observed to suffer from a decrease in attention, confusion (14.7 %) and loss of concentration (8.8 %) even though more than 50% of head chefs denied any psychological symptoms due to excessive heat. Impaired perception and impaired thinking were also reported (2.9 %) from kitchens. Symptoms of heat strain were observed among 14.7 % of staff.

11.3.2 Ventilation and humidity

11.3.2.1 Ventilation

i. Air movement in the kitchens was attributable to a combination of natural ventilation and fans. Approximately 79 % of the kitchens had deliberate inclusion of natural ventilation in the design. The sea breeze of coastal Durban was observed to improve airflow through large open doors and windows in the kitchens. High velocity heavy-duty industrial fans in 24 % and turbine ventilators in 18 % of the kitchens compensated for shortfalls in airflow.

ii. The ample height of the kitchen ceiling with a mean of 3.03 m and a maximum of 4.17 m enabled airflow. Two kitchens with especially large corridors were effective in channelling and delivering airflow into parts of a building. The practice of open kitchen doors in 55 % of kitchens permitted airflow of 0.10 m/s to 2.5 m/s that helped reduce ambient temperature and eliminate stuffiness. Additionally, the half walls used in zone partitioning in two kitchens permitted air distribution.

iii. However, common to kitchens where 30 % of the kitchen workers considered the workspace to be inadequate, the reported low rate of airflow is questionable. The area of the kitchens varied between 17 m^2 to 334 m^2 and the mean value was 68.41 m^2. The calculated volume of sampled kitchens ranged from 43.58 m^3 to 426.05 m^3.

iv. Airflow was mediated by measures of kitchen air velocity ranging from 0.00 to 2.5 m/s. Less than 60 % of the kitchens had adequate airflow rate of 0.5 m/s in all kitchen areas. About 56 % of the kitchen workers complained about inadequate airflow as 12 % of the kitchens had no airflow at all in some areas. Almost 27 % of the kitchen workers complained that airflow was inadequate over peak periods and 33 % of the workers affirmed the ventilation ineffective.

v. The thermal plume in 35 % of the kitchens was pushed into the cooker hood by domestic and heavy-duty fans. Nonetheless, almost 59 % of the workers experienced thermal discomfort due to poor airflow.

vi. The variation of the kitchen workspace ratio to a high density of 21.23 is unfavourable for individual ventilation need. The number of kitchen workers on the same shift varied from four to 17.

vii. The measure of toxic compounds levels of kitchen emissions of CO_2 ranged from 401 ppm to 2517 ppm. About 70 % of kitchen emitted CO_2 within published guidelines of 1000 ppm whereas kitchen zone measures indicated that 80 % of the different kitchen areas had CO_2 levels below 800 ppm. The presence of CO_2 in the sample frame was observed to be affected by the efficiency of extractors, drafts and the layout.

11.3.2.2 Humidity

i. The relative humidity peaked at 60 % in most kitchens. Twelve percent of the kitchen managers affirmed that existing ventilation was deficient in maintaining optimal humidity levels and good air quality. The raised humidity levels in cooking and dishwashing areas increased thermal strain in 40 % of the kitchens.

ii. The use of partial Eta (ɳ) revealed that cooking fusion cuisine has a medium to large effect on humidity whereas oriental cuisine has a small effect. Fusion cuisine obtained a higher value of ɳ= 0.091, a value close to 1 indicating a high degree of association, however, oriental cuisine obtained a lower value of ɳ= 0.027.

iii. As regards the effect of height on humidity, the best fitting predictive linear model indicates that for every unit increase in worker height a 0.161 unit decrease in humidity experience near the stove area value is predicted; this may be explained by the shorter chefs observed to work closer to the stove.

iv. A further multiple regression equation of predictor variables for humidity near stoves confirmed that genotype-ethnicity, mechanical devices for ventilation and physiological and psychological symptoms lead to heat stress.

v. Drafts from fans caused discomfort and could be prevented by lower fan speeds observed in the three kitchens. Three commercial kitchens had installed perforated perimeter air supply to cool off the chefs without any drafts. However, the system was functioning only in kitchen 6. The correlation between adjusting oscillating fans and clean oscillating fans was statistically significant $r[13] = +.698$, $p = .008$, two-tailed which means that kitchen workers have access to clean fans.

The minimal use of gas as fuel means less CO_2 released and less humidity in kitchens; the wet floors will accordingly dry faster. In this regard, the best fitting model for predicting humidity near stoves is a linear combination of floor is dry/wet. For every unit increase in dry floor, expect a 359.179 unit decrease in CO_2 near stove areas may be expected, holding all other variables constant.

11.3.3 Noise

i. Beyond the noise from regular cooking activities, kitchen noise was observed to stem from kitchen appliances and verbal communications between the cooks. External noises were negligible; therefore, not accounted for in the study.

ii. The continual drone of extractors constitutes continuous noise whereas recorded cooking equipment noises were in combinations of continuous, intermittent and fluctuating. The whistling of equipment such as boilers and pressure cookers constituted 10% of fluctuating noise. The highest intermittent noise was estimated to be 35 % from staff talking.

iii. The mean noise values across different kitchen areas ranged from 43.2 dBA to 76.35 dBA. Potato peelers and salad dryers in the food preparation zone of the three kitchens were the source of noise levels higher than 80 dBA. The cooking zone noise ranged from 53.20 dBA to 75.26 dBA. While most kitchen stoves emitted noise levels ranging from 64.00 to 85.50 dBA, with higher emittance from gas stoves and lower values from electric stoves. Fryers and grillers recorded mean noise levels of 68.19 dBA and 53.20 dBA respectively. Almost 10 % of the head chefs subjectively ranked gas stoves, boilers and steamers as the notable source of noise in kitchens followed by ovens and fryers. Exploratory factor analysis revealed the component named Noise index for noise from ovens, boilers and steamers, gas stoves and fryers. The highest loading of 0.897 for gas stove noises indicates its dominant influence on the variable.

iv. Furthermore, factor loadings of 0.612, 0.917 and 0.900 for unable to communicate, grinders making too much noise and noise from fans respectively; noise from grinders being the most influencing factor on the noise levels in the preparation area and contributing to discomfort element. Factor loadings were used as correlation coefficients between observed variable such as noise in the preparation area and latent common factors such as discomfort elements. Another exploratory factor analysis revealed a factor loading of 0.877 and 0.877 for a dishwashing machine producing noise and heat respectively. The significant p-value -.649 indicates that due to noise levels in kitchens, the kitchen workers were unable to communicate with co-workers. Similarly, staff were unable to communicate with co-workers due to noise in the kitchen having a p=0.504 with a significance level of 0.002 with staff complaining about noise in the kitchen.

v. The holding areas in the sample frame exhibited negligible noise with a mean of 71.53 dBA. Intermittent raised levels were, however, recorded for the ringing of orders at a high of 82.5 dBA.

vi. The highest noise levels were in dishwashing areas with a mean of 76.35 dBA and noise levels ranging from 65 dBA to 79.8 dBA. In this regard, the noise of the wash cycle was perceptible in 17 % of the sampled kitchens. The use of dishwashing machines was confined to 36.4 % of the kitchens, with 33.3 % of the kitchen personnel expressing discomfort with the noise from dishwashers. It was noticeable that in 51 % of the kitchens, the noise from extractors was greater than 40 dBA; the higher noise levels ranging from 70 dBa to 83 dBa. A strong negative correlation (p = -0.894) was achieved between noise from air conditioners and noise from HVAC systems with a significance level of 0.041 denoting that both pieces of equipment in a kitchen need not be noisier.

vii. The interviews revealed that 11.5 % of the workers thought that higher noise levels in kitchens was a problem and they could be prone to hearing loss. Specific criticism of kitchen level noise from head chefs were approximately 70 % in respect of blenders and grinders, 58 % of extractor noise and 85 % about stoves and fans. Almost 47 % of the kitchen managers responded that the kitchens had no problems with noise.

viii. The effect of partial eta squared indicated that whilst reaction to stove noise is affected mildly by the age of the worker and race, a moderate effect is observed by the gender of the kitchen worker that varies widely between males and females.

11.3.4 Lighting

i. Almost 95 % of kitchens used fluorescent lights in all the kitchen areas, except in pick-up sections and some canopy hoods of cooking areas. Pick-up sections used infrared lamps, ultraviolet lamps and sodium lamps; canopy hoods of cooking areas used incandescent globes.

ii. The lighting design in kitchens was found to be poorly planned in 36.4 % of the sample frame, as was evidenced by inadequate lighting in kitchen areas. Less than 50 % of the kitchens were found to have adequate lighting in cooking areas. Additionally, the lack of local lighting in 70 % of the kitchens suggests inadequacy in the number of light sources.

iii. The researcher’s appraisal revealed that 85.2 % of the kitchens with no skylights had unsatisfactory lighting in some kitchen areas; more than 21 % of the kitchens had unsatisfactory natural light. Less than 50 % of the kitchens have adequate lighting in cooking areas. The result of the exploratory factor analysis revealed factor loadings of 0.955; 0.932 and 0.895 respectively in preparation, cooking and dishwashing areas with regard to lighting in the kitchens. These loadings indicate the extent of relevance of these areas in explaining the influence of lighting levels in kitchens with lighting in preparation areas having the most influence on area illumination. The correlation undertaken between adequate lighting on food preparation areas and adequate lighting in cooking areas was found to be statistically significant, r (32) = +.677, p = .001, two-tailed. This is a positive indication of worker lighting comfort in kitchens.

iv. An illuminance of 204 lux in almost 43 % of the kitchens constitutes adequate lighting in cooking areas, the source of which is mainly from lamps inside the canopy hoods. However, the dishwashing areas in almost 17 % of the kitchens were inadequately illuminated.

v. The association of the presence of natural light and skylight in a mathematical model improved lighting in preparation areas (Table 10.6 page 274). The escalation of the lighting measures to a multivariate regression model revealed the association of human well-being in the workplace (headaches) with a preventable cause (clean lights and fixtures). For every unit increase in clean lights and fixtures, a 112.08 unit increase in lighting in the preparation area was predicted, holding all other variables constant (section 10.5).

vi. The maintenance of lighting sources varied. Whilst a higher 71 % of the kitchens had clean bulbs, approximately 66 % of kitchens had clean fixtures. Almost 18 % of kitchen workers assumed that the light bulbs were not cleaned on a regular basis. Visual discomfort, strain and weakened eyes were likely in the flickering lights of 3.6 % of kitchens.

vii. The component Good Maintenance was elicited from three loadings of 0.875, 0.752 and 0.693 for equipment in good repair, adequate lighting and installation that entails regular maintenance compliance for better lighting in kitchens. The correlation between all the kitchen equipment is in good repair and work experience was statistically significant, $r(33) = +.591$, $p < .001$, two-tailed implying that of kitchen managers strongly agreed that all the kitchen equipment was in good repair. The correlation between lights clean and adequate lighting on cooking areas was found to be statistically significant, r (30) = + 0.592, p=.001. The p-value was .595 for correlation between the amount of light in the kitchen is considered by the researcher to be adequate and all kitchen equipment is in good repair with a significance level of 0.001. There was also a positive correlation between adequate light in the kitchen and all the equipment is in good repair with a p-value =0.595 and a chi-squared value of 33.529 and p=0.000.

vii. The presence of task lights and low ambient light in some spots created contrasting lighting effects in 9.1 % of the kitchens. The control of contrast and glare was evident as less than 4 % of the kitchens exhibited such spots. About 91 % of the head chefs and kitchen managers affirmed that their kitchens had shadow-free work areas. Exploratory factor analysis further generated factor loadings of 0.482, 0.947 and 0.947, for variables such as lights protected, presence of task light and presence of infrared light in the kitchen. The latter two variables have the most influence on precise fixtures. Staff complaints about the contrast in the kitchen have a negative correlation with p= -0.480 and inadequate lighting in the kitchen had a fair correlation with a significance level of 0.004. Staff are happy about lighting in the kitchen with p= -0.480 with a significance level of 0.004. Common magnitudes in the social sciences are low to moderate communalities of .40 to .70 (Costello and Osborne 2005: 4). The fewer the staff complaints about light contrast in the kitchen, the higher the incidence of adequate lighting in kitchens with staff being happy about it.

viii. The mean of opinions on lighting between kitchen workers and their supervisors differ substantially. Whereas only 73 % of the workers felt that the visual comfort at their workplace was satisfactory and is free from glare, reflections and contrast, a higher 93.9 % of the kitchen managers believed that employees could comfortably see their work without straining their eyes.

There were insignificant correlations for items related to the negative effect of glare, a deduction evidenced by 93.9 % of the kitchen managers indicating that employees can comfortably see their work without straining their eyes. Nonetheless, almost 7 % of kitchens exhibited indirect glare and only 1.2 % of the kitchen workers complained about the glare; 73 % confirmed glare-free lighting. The analysis indicated that p-value was .739 with a significance level of 0.001 and chi-square statistic of 66, for correlation between the staff complaints about the contrast in the kitchen and staff complains about the glare in the kitchen. About sixty-one percent (60.6 %) of the kitchens had no direct glare; only 3 % had direct glare.

11.4 Achievement of research aim and objectives

Up to this point, the study attempted to explore environmental ergonomics in restaurant kitchens in Durban as influenced by kitchen conditions of heat, lighting, acoustics, ventilation and humidity. In doing so, it is hoped that the study provided a nuanced description of an underexplored research area, the inherent challenges and its potential. This section will provide a summary of the alignment of the study with the four objectives.

11.4.1 Objective 1:

To examine indoor airflow, humidity, lighting and acoustics in restaurant kitchens.

This objective set out to assess the influence of indoor airflow, humidity, lighting and acoustics as environmental ergonomic parameters in commercial kitchens in Durban.

11.4.1.1 Ventilation and humidity

The use of natural ventilation and selection of mechanical devices to cope with the indoor airflow and humidity emerged as vital components in the management of kitchen ventilation and humidity. The discussion that follows will summarise aspects of these variables.

Natural ventilation and mechanical devices

i. Traditionally, kitchens and or dining hall of a restaurant have backdoors for deliveries. The management of commercial kitchens, especially those located in warmer regions, are encouraged to introduce measures to include the safe opening of back doors to assist airflow and improve kitchen ventilation. Bonderud (2015: 1) and section 8.2.1 support that doors be left open for improved air circulation. A security gate with or without wire mesh can be installed for pest control and safety.

ii. Kitchens must install whirlybirds on their roofs or the sidewall even in a crowded city as they remain operational in the absence of wind flow due to the stack effect. Section 8.2.1 and Solarwhiz (2018: 1), Whelan (2015: 68), Kegley (2016: 1) and Atkinson *et al*. (2009: 41) point out that strategically placed whirlybirds, fans and air diffusers will help to eliminate areas with no airflow or minimum flow and help with heat extraction in kitchen. Management of high humidity in coastal restaurants necessitates the installation of a dehumidifier near preparation, cooking and or dishwashing areas.

iii. The statements of Kosonen and Mustakallio (2003: 189) and section 7.6.2, 7.6.3 and 8.3.5 support the imperative that natural ventilation is necessary to supplement mechanical ventilation. Walker (2016: 1) and section 8.2 concur that fenestrations must be placed on the windward side of the kitchen buildings. Therefore, kitchen fenestrations must be placed on the windward side especially in a building in a crowded city or placed on the leeward side in an open space so providing natural ventilation that can supplement mechanical ventilation. Given the high attention to natural ventilation, a considered specification of operable windows, doors, ceiling heights and vents is indispensable. Especially, when taking into account that after a building construction has been completed, it is not always possible to restructure these. Such designs will foster sufficient ventilation that will reduce heat envisaged by Tamimi and Fadzil (2009: 370) and section 8.2. These provisions for natural airflow must be further enhanced by mechanical ventilation described in 8.2.2 and by Kosonen (2014: 2).

iv. High ventilation rates to maintain thermal comfort and air quality are especially needed in compact kitchens or higher density kitchens. The correct size, type and number of ventilation units required for any area is determined by the kitchen size, its use and location (Vent-Axia 2019: 1). Ventilation rates vary between food service facilities due to site- and equipment-specific factors such as operating hours and extraction system features (Better Buildings 2015: 2). Also, section 8.3 found that the operating rates of extractors with low airflow velocities alone would not be able to provide thermal comfort. Here, air-conditioners have been found to reduce kitchen temperatures, especially during summer to benefit indoor design of restaurant kitchens in Durban in respect of ventilation and humidity. It has a prediction quality in relation to Objective 1 per Kosonen (2014: 2), section 8.2.2 and section 8.3.5.

v. Section 8.2.2 illustrate that calculated distribution of impervious partitions in the kitchen spaces or equipment and shelving arrangement create divisions in kitchen spaces that better channel airflow. Atkinson *et al*. (2009: 43) suggest that furniture layout and internal partitioning must permit the intended flow path and open access to airflow.

vi. Creating small changes in layout as observed in kitchen 27, can improve ventilation and air quality. Movement of air entering from the backdoor carries the CO_2 generated during grilling into the rest of the kitchen and even corridors. The griller should be moved against the wall in front of the corridor which is opposite to the back door so that the fumes generated do not spread to other areas in the kitchen. Kitchens to be designed with optimal ceiling height to allow natural ventilation during free runs in uninsulated buildings. Provision of a large corridor in the building complex will facilitate greater air movement in kitchens.

Ventilation fixtures and fittings

i. Section 8.3.1 and 8.3.2 helped to conclude that a revision of the location and a better choice of supply air outlet can reduce draft. Kitchen 6 had a perforated perimeter supply that cooled the chefs without any draft. Therefore, a perforated perimeter supply unit with lower airflow rate fitted to heavy-duty equipment that operates at high temperatures decreases heat emissions and hence reduces thermal discomfort described by Clark (2009: 21).

ii. Some participating kitchens demonstrated severe hood placement weaknesses. The first ignored the imperative that grilling and broiling units should not be at the end of the hood. Clark (2012: 54) and the researcher in section 8.4 indicate that a design needs to locate high heat and smoke-producing devices toward the centre of the hood's length. The discomfort of staff was particularly high where the end of hood placement of gas-operated tandoors failed to capture its thermal plumes. Secondly, heat-generating cookers albeit moderate installed outside the hood zone generated kitchen CO_2 levels as high as 716 ppm. Thirdly, the improper extraction triggered by flaws in hood placement raised CO_2 levels in other kitchens to a high of 899 ppm, 1246 ppm and 1016 ppm respectively in sections 8.4.4 and 8.5.2.

iii. The grilling and broiling units should not be at the end of the hood. Clark (2012: 54) and section 8.4 indicate that high heat and smoke-producing devices should be toward the centre of the hood's length. Kitchen 16 was stuffy with odours during peak time, especially during summertime. The gas-based tandoor was added into the cooking area as an afterthought and was installed at the end of the hood. The hood partially covered the tandoor and failed to capture the thermal plumes efficiently causing discomfort to the staff most days.

iv. Kitchen 12 had a fryer and a sandwich maker installed outside the hood zone causing stuffiness in the kitchen. Serveries in the kitchen had CO_2 levels as high as 716 ppm because the fryer and flattop grill were added as an afterthought without any consideration for thermal plumes. The other sections of the kitchen also recorded high CO_2 levels due to improper extraction. The CO_2 levels (Table 8.7 page 216) were: receiving area-834 ppm, preparation area-840 ppm, gas stoves-899 ppm, fryer-844 ppm, pick up-852 ppm, dishwashing-836 ppm and corridor area-753 ppm.

v. The use of electric equipment per Haruyama *et al.* (2010: 143), and Leitner and Kajtar (2018: 30) in section 7.5.1 and 8.4.3 recommend that it is a cleaner fuel with lesser discomfort levels. However, despite the recognised benefit in section 7.5.3 of gas cooking being faster as borne over by Everyday Health (2017: 1), Haruyama *et al*. (2010: 143) and section 7.5.1 and 8.4.3 highlight a downside of kitchen workers exposure to higher heat strains than those in electric kitchens. While there is this environmental ergonomic rationale, a mix of electric and gas equipment that leans to the former would be a prudent choice, particularly for reducing emissions and decreasing temperature levels.

Air extractors

i. Shortcomings in kitchen ventilation results in discomfort and health risks from high volume cooking. These are alleviated by extraction techniques such as those in section 8.3.4 that trigger increases in the volume of displaced air and enhance airflow ventilation rate at a minimum of 0.5 m/s. Also, exchanging stale air for fresh air that expels humid and odorous air from kitchens (Clausing 2015: 1) are necessary aspects expounded in section 8.4.

ii. The space between stove tops and installation height of the kitchen canopy hood affects the performance efficiency of the latter (Bhatia 2012: 9). The ineffectiveness of canopy hoods in section 8.4 is attributable to its installation exceeding the optimal of 60 cm per Sjaastad and Svendsen (2010: 267). Placing the hood at a distance far above the appliance increases opportunities for leakage of thermal plume that dissipates quickly with an increase in distance (Han *et al*. 2019: 8).

iii. The fieldwork in section 8.3.4 indicates that immediately after cooking sessions some kitchens ran the extractors at lower rates to save on energy. Dobbin *et al*. (2018: 286) contest this practice and section 8.3.4 in that extractors must run at maximum for a short time after cooking to exhaust heat and pollutants efficiently. In fact, these should run at maximum flow rate during and after busy periods (Sjaastad 2010: 53).

iv. The empirical evidence in section 8.7.1 indicates that the effectiveness of the needed flow rate depends substantially on the nature of extractor maintenance. While staff reported the efficiency when newly installed, most complained that the kitchen grew very hot, stuffy and humid during summer.

v. Where there is a small overhang of the extractor hood, Fisher (2015: 34) and section 8.3.4 show that the kitchen hood system is unable to capture and contain the rising thermal plume containing CO_2 from the cooking equipment. The empirical results in section 8.4.2 illustrate clearly that the overhangs less than 60 cm encourage unwanted dissemination of effluent across all kitchen spaces that overwhelm existing cross ventilation.

vi. Changes subsequent to extractor installation in equipment or work area have not been accompanied by any assessment and modification to canopy hoods. The changes indicated in section 8.4.2 have affected the precision and alignment of the hood with the cooking equipment. These do not, therefore, accord with Bhatia (2012: 9) and section 8.3.4 needing the hood lip to extend over the outer end of cooking appliances.

11.4.1.2 Noise

i. The installation of kitchen noise-absorbing materials contended in Forouharmajd and Shabab (2015: 49) and revealed in section 9.4 has the potential to manage noise. These can be in combinations of sound-absorbing materials fixings under its work tables, shelves and cupboards, echo-absorbing insulation to its ceilings, noise-catching aluminium ceiling panels, soundproofing treatments on the doors and the use of soundproofing paint.

ii. Kitchen maintenance routines impact significantly on noise management (National Institute for Occupational Safety and Health 2015: 1). Deficits in control and remediation illustrated in section 9.3.3 negatively affect staff hearing capacity and eventually with daily exposures their general well-being. Fischer *et al*. (2014: 1) and section 9.5.1 support that maintenance contributes substantially to noise control in kitchens. The contribution is especially significant for extraction systems across kitchens and those using mechanical equipment. Walia *et al*. (2010: 1) and section 9.5.1 accordingly suggest an appropriately budgeted preventive and routine maintenance program.

11.4.1.3 Lighting

i. Inadequate attention to kitchen lighting is a significant contributor to eyestrain. This view is not unknown as Jensen (2019: 1) contends that dim lights can cause eyestrain and headache as lighting is inadequate, as confirmed in section 10.5.

ii. There is a need for precision in many kitchen operations (Die-Pat 2016b: 1). Section 10.5 confirmed that poor lighting when accuracy is needed causes eye fatigue or eyestrain. The need is previously recognised in Aries (2005: 54).

iii. As indicated in the literature, attention to the management of glare, contrast and reflections offers visual comfort in kitchen work and avoids musculo-skeletal detriment among kitchen workers (Dunaief 2018: 1; Wiholm *et al.* 2007: 54). Whilst section 10.5 affirmed that bright lighting in kitchens is harmful and reduces well-being among workers and section 10.5.5 report that glare was minimal in the sampled kitchens.

iv. The statement of Jensen (2019: 1) and section 10.3.3 supported that natural lighting is superior. Kitchens should have access to sunlight for a better worker attitude. Sunlight has a positive effect on workers' subjective well-being, and workers prefer to work with natural lighting. The five restaurant kitchens had windows that were closed off failed to recognise that the practice flouts the positive effect of sunlight on workers' subjective well-being (Marcheso-Moreno 2019: 1); 50 % of the kitchens in section 10.3.3 are shown to have no windows and hence natural sunlight was denied to the staff. Imprudent design by way of inoperable windows and uneven distribution of natural light in the kitchen further disadvantaged kitchen workers. However, tasks necessitated installations of artificial lighting to enable work processes.

v. The lack of awareness of owners and chefs on regulations for lighting specifications in the kitchen indicated in section 10.4.1 exacerbated kitchen worker vision-related symptoms. The nearly 40 % of kitchens with inadequate overall lighting along with 85 % deficiency in specific work areas, disadvantaged kitchen workers.

vi. While minimally indicated in section 10.2, procedures for attention to non-functional artificial lighting ought to be consistent. The effective maintenance of natural and artificial lighting sources is a key contributor to visual comfort (Home and Garden TV 2019: 1). In addition, inefficient lighting maintenance is shown in section 10.5 to result in a loss of intensity due to the accumulation of dirt and dust.

vii. Section 10.2 reported the necessity for appropriate lighting on the stoves and grilling areas. The reliance on ceiling lighting and the absence of lighting fixtures in the canopy hoods in 45 % of kitchens failed to reach the required levels indicated in Radcliff (2018: 1). However, a majority had functionally compliant installations.

viii. The practice of kitchen workers having control of lighting is favoured in section 10.5.1. Personal control of lighting was shown in Gifford and McCunn (2018: 111) to hold positive results for the well-being of workers in enclosures. The potential for better visual comfort may be enhanced.

11.4.2 Objective 2:

To determine the thermal environment and heat stress amongst food production workers using gas and electrical kitchen appliances.

In pursuit of the second study objective, the study revealed that kitchens are typical workplaces with a hot indoor environment. Improvement in the kitchen environment occurred due to the introduction of electric stoves instead of the use of gas stoves.

11.4.2.1 Kitchen thermal environment

i. Almost 70% of the sampled food service workers claimed that they experienced kitchens as hot working places in section 7.6, as was also reported in Logeswari and Mrinalini (2017: 607). Heat production in the sample frame was influenced by the use of equipment, cuisine (menu and cooking methods), individual human factors and activity. As regards equipment, exploratory factor analysis in section 7.4.1 revealed that the four main kitchen equipment namely ovens, boilers and steamers, gas stoves and fryers and fit into a single loading of the subcomponent called large appliances that impact on heat production. Only a single central kitchen used electrical equipment to cook large volumes of food and a chicken franchise used electrical pressure fryers to prepare fried chicken. The medium-duty kitchens used electricity extensively, although the heavy-duty kitchens widely used gas appliances. Table 7.17 (page 173) in section 7.5.2 positioned stoves and ovens as primary heat generators in kitchens. The recorded temperatures were comparable with Simone *et al*. (2013: 1007), Saha *et al.* (2012: 183) and Li *et al.* (2012) in Table 7.20 (page 176).

ii. Kitchens with equipment that categorise them as extra-heavy-duty kitchens have higher ambient temperatures and emissions as per IMC (2015: 58). The temperature ranged from 30.66° C to 32.20° C in extra heavy-duty load kitchens, also featured in early reports of Heinonen (1997: 124). The 10 % increase in temperature is attributable to heavy use of ranges, frying pans, fryers and grills. The substantial use of LPG contributed to the expected higher values near grillers releasing smoke and humidity and causing thermal discomfort.

The discomfort index near the stove in the present study was modelled on the equation Y = b0 + b1x1, indicating that the discomfort index near stove = 49.152 + (2.013 x heat near stoves). For every unit increase in heat near stoves, a 2.013 unit increase in discomfort index value is predicted, holding all other variables constant. The stove fuel type (IMC 2015: 58) nonetheless, influences the discomfort index.

iii. Liquid petroleum gas (LPG) and solid fuels generate extreme cooking temperatures as they cook at temperatures of 371° C to 480° C (Shah 2013: 1). On the other hand, the cook-chill systems can assist in lower heat production by lower temperature ranges from 25° C to 28° C with reduced heat stress during peak periods by preparation of certain items in advance. The cook-serve method was very popular in the sampled kitchens.

vi. The cooking fuels in the sampled kitchens varied with the cuisine on offer. At the higher end, cuisines prepared by stir-frying with gas stoves cook at approximately 300° C (Lin and Liou 2000: 817) contributed significantly to heat in kitchens. Indian cuisine kitchens used gas stoves for all cooking except frying. Mexican restaurants used gas for preparation of sauces. Italian food was served at more establishments in the sample frame than any other (23.5 %), ranging from pizzas only to a wide variety of pasta and antipasti as indicated in section 7.4.4. Three kitchens used electrical pizza ovens extensively, and another three kitchens had a combination of wood-fired ovens and electrical ovens whereas, only one kitchen had a gas tunnel oven.

v. The cuisine varied widely in casual, institutional and quick-service restaurant kitchens. The mean values indicate that wet-bulb globe temperature was highest near electric ovens (27.28° C) in the casual restaurant kitchens, whereas grillers (30.40° C) recorded higher values in institutional kitchens and fryers (30.16° C) in quick-service restaurants. The number of meals cooked per day incidentally and heat generated from the equipment impacts on the heat produced. A majority of the respondents served less than 250 meals per day (76.5 %) ($p = 0.004$), however, 23.6 % served more depending on the day of the week. The sample included a kitchen servicing a coffee shop with a lower food production volume generally using electricity, but only gas for grill dishes. The substantial lower kitchen temperature recorded in this kitchen was 28º C. Welch (2017: 14) reports that higher production kitchens had a significantly greater increase in Heat Index compared to low production takeaway kitchens.

vi. As expected, more than 80 % of the respondents indicated that it was hot during peak hours ($p < 0.001$). Staff in kitchens expressed a higher number of complaints with no vent, diffuser, or air-conditioner in the kitchens. The discomfort indices indicated that staff in Durban kitchens are uncomfortable during peak periods of business. The implication of peak hours on the indicators of heat stress is to be raised later in this section. Almost 33 % of head chefs responded that inadequate cooling in the kitchen was causing high temperatures and, 41 % of kitchen staff found the thermal environment uncomfortable. This is supported by the wet bulb globe temperature that ranged from 27.13° C to 35.58° C in this study that resonates with those of Simone *et al*. (2013: 1008). This is much higher than the permissible limit of corrected effective temperature ranging from 23.0° C to 25.0° C as per ILO regulations (Maruthi *et al.* 2013: 4).

vi. The thermal experience by chefs was found to be associated with job position, work shift, type of kitchen load, years of employment and race. Except for grillers and bakers, other chefs and kitchen workers were not directly exposed to stove heat. The adoption of the equation Y = b0+ (-b1)*x1 + (- b2) *x2 + (– b3) *x3 + (– b4) *x4 indicates that secondary factors affecting heat perception near the stove = 35.341 + (-0.103 x job position) + (-0.091 x years of employment) + (-0.403 x worker shift) + (-0.722 x type of kitchen). The best fitting model for predicting heat near the stove is, accordingly, a linear combination of type of kitchen, job position, years of employment and worker shift.

vii. The heat experienced by kitchen workers near stoves were influenced by the kitchen ceiling height, staff/space ratio and state of staff uniforms. The experience manifested in discomfort indices were physically indicated by the face-red and sweating of kitchen staff. However, only symptoms of red face ($p=0.012$) and Discomfort Index ($p=0.00$) had significant values. This p-value determines that the relationship observed in this sample also exists in the larger population of kitchens.

The regression Y = b0 +b1 * X1 +b2*x2 implies that

Heat near stove = – 6.795 + (– 2.162 x symptoms red face) + (0.446 x Discomfort Index) per section 7.5.4.2 . Tests for multi-collinearity indicated that a very low level of multi-collinearity was present (VIF = 1.141 for symptoms face-red and 1.127 for discomfort index (Stove/Oven). This means that these two independent variables are highly distinct.

According to South African Weather Services (2020: 1), the wet-bulb globe temperature index is the impact of heat stress on an individual and a combined effect of temperature and humidity. Thirty-nine percent (39 %) of chefs and kitchen managers responded that humidity was high, and more than 48 % indicated that staff complained about humidity (section 7.6.3).

11.4.2.2 Effect of gas and electrical appliances on heat stress

i. The heat index in kitchens was objectively measured using direct indices and, also subjectively by observing indicators of heat stress and workers opinions. The operating temperature, humidity levels and wet bulb globe temperatures near stoves were measured and discomfort indices were subsequently calculated. Notably, in this regard, the European Agency for Safety and Health at Work (2008a: 71) confirmed that high surrounding temperatures can lead to discomfort and even heat stress at a wet-bulb globe temperature index of 26.8° C.

ii. Up to 60 % of the heat produced by a gas burner is wasted as it escapes into the air (Joachim and Schloss 2017: 4). The excess heat produced from the open flame of an LPG cooker preference (58.5 %) in Table 7.13 and discomfort in Table 7.25 (page 181) increases heat stress. Section 7.6.2 disclosed that the food service workers were uncomfortable during peak periods of business, pointing to greater heat stress levels during this period. According to Epstein and Moran (2006: 388), measures of heat stress are directly determinable by the discomfort index. The data indicated that the kitchens with heavy-duty load yield higher discomfort values (Table 7.26 page 182) than other kitchens from extensive use of LPG equipment, hence raising the heat stress of the kitchen workers. On the other hand, in medium-duty kitchens, there is a preponderance of electric equipment use. Hence, Haruyama *et al*. (2010: 143) also found that workers in LPG fuelled kitchens may be exposed to higher heat strains than those in electric kitchens. Almost 74 % of the energy produced on an electric range is transferred to food, compared to about 40 % on a gas range (Schwartz and Vila 2020: 3) whereas induction cooktops transferred up to 90% of the energy to food.

iii. National Institute for Occupational Safety and Health (2016: 71) observed that flushing is among heat stress symptoms. This physiological response to heat stress was expressed in the current study by the equation Y = b0 + b1x1 namely, Heat = 32.907+ (10.152 x symptoms-red face). Thus, flushing may be expressed in the equation Y = b0 + b1x1 namely, Heat = 32.907+ (10.152 x symptoms-red face). Thus, for every unit increase in red-faced chefs as symptoms of heat stress, a 10.152 unit increase in heat near stove area value is predicted, holding all other variables constant. Since p=0.010, less than the significance level of 0.05, there is strong evidence to conclude that the variables are associated. Whilst only 15.2 % of the workers were red in the face from the heat in cooking areas, the statistic could be misleading as 78% of African workers were dark in complexion due to ethnicity and hence it was not apparent; some Indian chefs were also darker in complexion.

iv. More than 45 % of the sampled kitchen workers showed physical symptoms of heat stress from electrical and gas equipment (Table 7.14 page 173); however 18 % of the supervising head chefs reported that they did not experience heat stress; symptoms of heat stress observed by head chefs (Table 7.27) in the sampled kitchens. The discrepancy may amongst others, be attributable to lack of supervisor observation of staff not reporting appropriately to their supervisors. The use of a combination of electrical and gas appliances was common to these kitchens.

v. National Institute for Occupational Safety and Health (2016: 71) observed that sweating is among heat stress symptoms. More than 57 % of kitchen workers in the current study reported that they sweat in the work environment. Sweating was obvious among 11.1 % of staff. Heavy sweating, along with headaches was reported by 3 % of the workers. Another 3% of the chefs reported high blood pressure and feeling of sickness. The most prevalent consequence of heat stress was reported to be manifested in tiredness and intense thirst, commonly conveyed by 35 % of kitchen workers. Amongst others, Xiang *et al*. (2014b: 90) also maintain that heat stress can cause negative behavioural effects such as physical fatigue, irritability, lethargy, impaired judgement, vigilance, and decrement, loss of dexterity, coordination and concentration. Notable, the present study established that amongst the sampled kitchen workers 23.5 % suffered from a decrease in attention and or irritability, 14.7 % from confusion, 8.8 % loss of concentration, and impaired perception and impaired thinking were each reported at 2.9 %.

11.4.3 Objective 3:

To investigate the perception of food production workers' adaptability to selected indoor environmental conditions.

As per van Dam (2009: 127), employee adaptability is relevant in stressful work environment. An increased understanding of individual adaptability will contribute to a better understanding of employee behaviour, performance, and well-being in complex and changing work environments.

i. The present research assessed the perception of work stress experienced by the kitchen workers in the commercial kitchens attributable to selected environmental parameters in line with

Hima Bindu and Reddy (2016: 1320) and Simone *et al*. (2013: 1006). The research elicited information on the perception of work stress of kitchen workers by kitchen supervisors. Consistent with Giousmpasogloua *et al*. (2018: 1) head chefs' responses were solicited to obtain perspectives of the coping strategy in kitchens from heat.

ii. Specific factors raised by kitchen worker supervisors of their subordinated workplace adaptability to heat were revealed as age (59 %), task experience (47 %), fitness (20.6 %) and body weight (14.7 %). These adaptation features of heat also raised in Farnell *et al.* (2008: 238) lend credence to supervisor perception. The race of workers was also raised by 37.5 % of the kitchen worker supervisors as important to the ability to adapt to heat in the kitchen. In this regard ethnicity, is cited in Farnell *et al*. (2008: 238) as among the likely influencers of an individual's response to thermos-regulation

iii. A combination of factors, including ethnicity, may influence an individual's response to thermos-regulation (Farnell *et al.* 2008: 238). Socio-cultural aspects influence heat-stress perception in the workplace according to Messeri *et al*. (2019: 9). The primary data when subjected to exploratory factor analysis, located socio-economic index with loadings of 0.801, 0.400, and 0.672 for age, work experience and correct body weight as influencing kitchen heat adaptability. While a lower socio-economic standard may according to Dzhambov and Dimitrova (2014: 95) make for displaced aggression, no mention of this perception was revealed in the primary data. While kitchen workers with higher socio-economic status are more likely to be obese (Najafi *et. al* 2020: 1), shift times of kitchen work render kitchen workers susceptible to a raised body mass index.

iv. Increasing fitness appears to foster a reduction of thermal discomfort during work despite physiological strain (Cheung 2010: 53). Such perception of fitness had influenced kitchen workers' adaptability to kitchen thermal conditions. Almost 86 % of the kitchen workers believed that they possessed fitness (Figure 7.4) although Table 7.3 indicates a smaller percentage. Nearly 30 % of head chefs/managers felt that fitness did not affect surviving heat in the kitchen; 70 % felt that it played an important role (Lisman *et al*. 2014: 1339). Each female worker assumes she is 1.45 times physically fitter than she actually was, which helps the female worker to cope with heat better as this has a positive psychological effect (Table 7.9 page 163). Also, shift times of kitchen work in Section 7.3.2 is perceived as being likely to impact on kitchen workers susceptible to raised body mass index.

v. Section 7.2.6 reveals that years of employment and work experience influence heat experience. An estimated 47 % of head chefs strongly agreed that kitchen work experience played a substantial role in managing heat adaptability; also, the years of employment contributes to work experience and acclimation to heat. Work experience varied from three months for a trainee chef to 35 years for a 60-year-old chef. In this regard, daily routine activities involving physical activity in the ambient heat lead to partial seasonal acclimatisation that improves population heat tolerance. Lundgren-Kownacki *et al.* (2019: 10) suggest adopting a systematic heat exposure regime to induce acclimatisation, giving kitchen employees time to adapt to the workplace prior to taking up the job.

vi. Similarly, with respect to lighting, almost eighteen percent (17.6 %) believed that tenure of work in commercial kitchens enables kitchen workers to see in lighting available in kitchens. While age is an important determinant of vision, only 8.8 % believed it influenced vision. According to the American Optometric Association (2020: 2), eyes and vision change over time and workers need more light to see. Brighter lights in the work area will help make close-up tasks easier. Amongst others, Kunduraci (2017: 185) affirms that older people require more illuminance than their younger counterparts. In this regard, section 10.4.3 indicated that 76 % of the kitchen workers perceive that the lighting needs of older workers were met.

vii. The extent of noise discomfort was perceived to be influenced by kitchen worker age. Section 9.3.4 indicated that 38.2 % of kitchen managers (38.2 %) perceive age as the foremost natural factor in adapting to kitchen noise understandably, as age is a significant possible cofactor of noise-induced hearing loss. The role of work experience (41.2 %) also seemed to be in psychological preparation for the expected kitchen noise level.

viii. Although 67 % of kitchen workers indicated they are unaffected by kitchen noise, 11.5 % perceived that noise levels at their workplace may affect their hearing. However, intermittent noise from blenders as a nuisance was reported by 91 % of kitchen workers in the present study. According to Erickson and Newman (2017: 452), intermittent noises are likely to cause greater distraction. Nearly 35.3 % of kitchen workers responded that they have to raise their voice to talk to a colleague one meter away. According to Gorvett (2019: 2), conversations were rated the most disturbing as workers are better at complex tasks in total silence.

ix. A majority of kitchen workers perceived that their workstations are free of glare, reflections and contrast, to the extent that 73 % of the workers felt that the visual comfort at their workplace was satisfactory. The remaining staff may experience according to Dudeja *et al.* (2016: 366) distraction and annoyance caused by the effects of reflections and glare.

x. While Nyilo and Putri (2019: 88) report that mostly kitchen workers (68.75 %) comprising females (58.33 %) suffered from noise-induced hearing loss, an approximation of only 6 % of the head chefs perceived that gender affects adaptation to noise in kitchens. In fact, the perception of differences in noise tolerance was more attributable to race. Nearly, 21 % of the head chefs perceived that race is an important factor in adaptation to noise. The skin pigmentation as a marker of melanocytic functioning may mediate the strong association observed between ethnicity and hearing loss (Lin *et al.* 2011: 109). Fligor *et al*. (2014: 1535) reported from a survey on noise that 60 % of Africans exceeded the daily and weekly allowance for noise compared to 86 % of African Americans.

11.4.4 Objective 4:

To compose indoor environmental criteria for design of restaurant kitchens in Durban in respect of indoor airflow, humidity, thermal environment, lighting and acoustics.

The upgrading essential to advance kitchen environment was discussed here. The statements of criteria improvement will better assure worker well-being and overall comfort levels in commercial kitchens. The indoor environmental criteria for the design of restaurant kitchens in Durban is accordingly enumerated in the sections that follow along with relevant rationale.

11.4.4.1 Indoor airflow

i. Maintain air velocity consistent at 0.25 m/s to 0.5 m/s in all areas of kitchen workstations.

The range from minimum to maximum across all kitchen work areas varied from 0.00 to 2.5 m/s. The range of 0.06 m/s to 0.42 m/s in casual and quick-service restaurants respectively was found to be highly inadequate as witnessed by frequent complaints, especially during summer (Appendix 11). An airspeed of 0.25 m/s (Cengel and Boles 2007: 729) in a commercial kitchen can be comfortable and slower than 0.5 m/s (Boduch and Fincher 2009: 3) feels pleasant. Managing within these ranges are especially necessary when relative humidity is high (Bridger 2003: 255) earlier found that airspeeds of 0.2 m/s to 0.5 m/s helped in body cooling in hotter conditions.

ii. The staff/space ratio must be no less than or at 13 m² per employee in any kitchen shift; a minimum of 2.25 m² of unimpeded space of open floor area is to be available for every employee working in an indoor workplace.

The number of staff members per m² (workspace ratio) of indoor space varied from 2.67 m² to 21.23 m² in the sampled kitchens. Medium-duty kitchens were found to have the highest workspace ratio of 10.16 whereas extra-heavy-duty kitchens had the lowest ratio of 5.60. The most common heavy-duty equipment kitchens (61 %) had a workspace ratio of 7.88 and light-duty kitchens had a ratio of 9.4, classifying them both as a high-density workspace as per Simmons (2019: 1), instances where workspaces of 7.4 m² to 13.9 m²/employee are considered as high density in office. In this regard, Energy Code Ace (2013: 2), California Building Code recommends 18.58 m²/occupant for commercial kitchen occupant density. There is no convincing evidence that staff/space ratio for commercial kitchens in subtropical locations had received attention in the literature. Smith (2018: 1) reports that workspace of 13 m²/employee in restaurants in the U.K is acceptable whereas, the national average was 18 m² per employee in the USA.

iii. Determination of kitchen size based on restaurant seating, is the most effective metric to inform airflow requirements.

Ideal kitchens should have larger areas as it seems to influence the airflow in the kitchen taking into account the menu, cuisine and number of meals cooked. According to Allen (2014: 2), most restaurant kitchens feature several pieces of high-intensity cooking and dishwashing equipment packed into a relatively small area affecting the air quality with poorer airflow. Debnath *et al.* (2017: 705) observed that a factor like airflow within the kitchen space is given little consideration

The minimum size of a kitchen with accommodation of up to 50 seats must be at least 20 m² including the washing area. For greater receptivity or better service experience, 0.5 m² per seat is calculated (Biblus 2020: 3). Behmen (2020: 3) confirm that for every seat in the restaurant, at least five square feet (0.46 m²) of kitchen space is to be provided. Similarly, the rule of thumb for kitchen size is to allocate at least five square feet (0.46 m²) for every seat in the dining area (Manu 2019: 1). The size of commercial kitchens as per City of Durban (2020) Food By-Laws (Provincial Notice No. 627 of 1950) specifies that a 60-40 ratio is a baseline for allocating space, 40% allocated to the kitchen, storage and preparation areas. Papandrea (2019: 1) recommends that the kitchen should take up about 30 % to 40 % of the entire space and the balance of 60 % to 70 % is for the dining area.

The need for fresh air in the workplace is influenced by the space available per occupant (Bhatia 2012: 3). Larger kitchen spaces leave unoccupied spaces that improve airflow to different areas in kitchens. The kitchen floor areas ranged from less than 100 m² to a few greater than 300 m² (Table 8.2 page 200). Kitchens 6, 7 and 14 had larger areas leaving additional unoccupied space for air circulation with kitchen areas ranging from 173 m² to 332 m². These kitchens prepared meals ranging from 50 meals an hour to 400 meals a shift including sit down, room service and takeaway

(Figure 7.6). About 30 % of the kitchen staff from other kitchens consider that the kitchen workspace was inadequate. A moderate alignment was observed as the meals prepared were divided into sit down and takeaway.

iv. Kitchens are to be designed with provision for mixed-mode mechanical ventilation and natural ventilation.

Almost 7% of the kitchens benefitted from the natural sea breeze. Parkinson *et al*. (2020: 1) claim that a mixed-mode design can minimise HVAC energy demand without compromising occupant thermal comfort. Five kitchens namely, 3, 7, 14, 19 and 13 had a good balance of natural and mechanical ventilation. The principles of hybrid ventilation were well applied where it combined the best of natural and mechanical ventilation. The combination of large corridors, high ceilings and open doors permitted sea breeze. With extractors assisting during the cooking mode, the kitchens maintained ambient temperatures of less than 30º C with a relative humidity of 55%. The airflow rates that varied from 0.3 m/s to 2.0 m/s were enabled by the sea breeze that diluted pollutants; the CO_2 levels were less than 600 ppm in all areas of kitchens. The positive influences of the sea breeze are underlined by Hong *et al*. (2007: 432), and Mohr *et al*. (2012: 1661) to effectively dilute the polyaromatic hydrocarbon from cooking.

v. Installation of perforated perimeter supply in cooking zones is necessary to prevent drafts in kitchens instead of fans.

Although fans installed in the kitchens in non-cooking zones assist in alleviating discomfort, the movement of fans caused drafts in cooking areas, disturbing thermal plume and sometimes leading to hot drafts. Han *et al*. (2019: 6) investigated the capture efficiency and containment of hoods and revealed that drafts in a commercial kitchen induced the most serious pollutant spillage of the thermal plume. Kitchen 6 had perforated perimeter supply installed above a range and the kitchen workers of that section always felt comfortable without any signs of discomfort or heat stress. The kitchen manager claims that the kitchen had acceptable ventilation. On the other hand, kitchen 13 had a perforated perimeter supply system that was not working. The kitchen workers complained about heat, stuffiness and stale air. The kitchen workers at times also complained about hot drafts in kitchens 13, 16 and 23 as fans have disturbed the thermal plume before entering the extractor if it was not fitted directionally accurately. As per Caple (2018: 4), steady air circulation must be provided in the kitchen and intrusive cross flows or air turbulence must be avoided.

vi. The dimensions of the extraction hood overhang, the hood shape, hood alignment to cooking equipment and height of hood installation must be of equal importance on hood design.

There was no valid indication in the literature that expand hood criteria for commercial kitchens sited in subtropical locations. A good alignment of the hood with cooking equipment and a hood lip extending beyond the end of cooking equipment is essential, smaller overhangs Chinese design hoods are unfavourable to good ventilation. The hood overhang of 0.1 m is the requirement stipulated by the Ministry of Housing and Urban-Rural Development, China (Zhang *et al*. 2020: 171). In the kitchens 16 and 12, the cooking equipment extended beyond the canopy hood lip and in kitchens 9, 28 and 33, the Chinese design hoods were installed, contributing to inadequate ventilation affecting the air quality negatively. Zhao *et al*. (2013: 144) observed that Chinese hoods affect exhaust efficiency because of the small hood volume. Kitchens 11, 17 and 18 had higher CO_2 levels of 899 ppm, 1246 ppm and 1016 ppm due to canopy hoods at a greater height above gas stoves namely, 75 cm from stove height. Shorter overhangs of 0.10 m could also lead to higher levels of CO_2 in these kitchens as 42 % of overhangs were less than 0.06 m, 12 % overhangs were only 0.10 m long. Placing the hood at a distance far above the appliance increases opportunities for leakage of the thermal plume that dissipates quickly with an increase in distance (Han *et al*. 2019: 8). Chandler (2019: 2) suggests that the hood be installed between 61 and 76 cm from the stovetop. Many hoods are simply installed too high and this significantly reduces their effectiveness.

vii. The installation of carbon dioxide detectors is necessary for commercial kitchens.

Measures of CO_2 levels in the present study ranged from 401 ppm to 2517 ppm in different kitchens. About 70 % of the kitchens were within the ANSI (Petty 2014: 2) and ASHRAE 62 (1989) guidelines of 1000 ppm (Appendix 13) whereas 80 % of the different kitchen areas had CO_2 levels below 800 ppm (Table 8.7 page 216). Grillers had the highest mean of 996 ppm for CO_2, whereas corridors towards the kitchen had the lowest average value of 506 ppm for CO_2. CO_2 detectors also indicate O_2 levels that helps to confirm that CO levels are within safe limits.

High levels of CO_2 affect the occupational health of kitchen workers and commonly associated with Sick Building Syndrome (Bierwirth 2018: 8). A CO_2-based demand-controlled ventilation (DCV) system can maintain adequate indoor environmental quality (Shriram and Ramamurthy 2019: 805). Pei *et al*. (2019: 8) reveal that the wall-mounted CO_2 sensors at breathing height can predict the breathing zone concentration with higher accuracy compared to the exhaust sensor in displacement ventilation.

viii. Heating, ventilation and air-conditioning systems/extractors must embrace the use of gas fuel emissions.

The results of sampled kitchens (Table 8.8 page 218) concur with Saha *et al*. (2012: 183) and Li *et al*. (2012: 150) in that gas grillers and gas stoves also produce higher CO_2 levels is as recorded in six kitchens that had levels > 1000 ppm near grillers (Appendix 13). CO_2 levels were high (>1000 ppm) near grillers and tandoors in 30 % of the kitchens. Higher emissions of CO_2 were evident amongst heavy-duty load kitchens (Table 8.7). The CO_2 level is not only related to the cooking time and cooking methods but also occurred as a result of burning gas (Zhao and Zhao 2018: 992). Jiang *et al*. (2012: 4435) claim that this has a serious impact on the physical health of staff.

xi. Proper upkeep of kitchen equipment to avoid unpleasant odours as clean cooking equipment reduces fumes and extractors improve air quality.

A minor proportion (5.3 %) of kitchens had soot-producing equipment such as grillers and ovens that were soiled and scheduled for clean-up. As per Rainbow International (2020: 2), exposure to smoke and soot can adversely affect the health of kitchen workers. Soot contains toxic particles leaving behind bad odours and stains (Puro Clean 2018: 2). However, almost 58 % of the kitchens had equipment that did not produce soot from burning of spills or unclean equipment.

11.4.4.2 Humidity

i. The provision of deliberately higher airflow rates in kitchens with those cuisines that generate higher humidity levels.

Lester (2020: 1) posits that humidity can wreak havoc in a commercial kitchen or a bakery. Kitchens are hot environments with higher moisture levels in the air. More than 10 % of head chefs felt that kitchens were humid and 15 % felt that it was sweaty in the kitchen as cooking various cuisines, especially steaming and boiling with special appliances, may raise humidity levels (Appendix 15). The high quantity of water vapour produced can contribute to high humidity (Kim *et al*. 2018: 1). For example, cooking fusion cuisine has a medium to large effect on humidity. On a more intensive level, cooking in a wok results in a significant contribution to indoor combustion and moisture. Li *et al*. (2012: 144) report relative humidity levels ranging from 45.6 % to 79.8 % in kitchens cooking Chinese cuisine. Section 8.5.3 indicated that humidity was higher in cooking areas near the stoves. Partial eta squared in Section 8.5.2 between humidity near stoves and type of cuisine is shown to negatively affect discomfort index near stoves. The problem can be solved by providing very high ventilation rates during the activity periods of cooking and washing using mechanical ventilation. Extract fans are effective measures of controlling the spread of moisture from these zones (Awbi 2003: 74).

ii. A dehumidifier is a requisite in commercial kitchens in tropical geographical areas.

The humidity levels varied from 32.00 % to 89.50 % in the sampled kitchens, although, the mean value of relative humidity was approximately 56 % which is within optimum levels. However, more than 10 % of head chefs felt that kitchens were humid. Appendix 14 indicated that griller and stove areas have higher mean values for humidity levels, whereas the trimmed mean values were higher for grilling and dishwashing. Moreover, ovens produced higher maximum humidity values compared to stoves and dishwashing (Appendix 14). Several close associations were established between the type of food service, cuisine and kitchen load with chi-square tests (Appendix 15), conversely, the study found that humidity was not a significant factor for Indian and Italian cuisine.

On the other hand, Rahmillah *et al*. (2017: 6) claims that thermal comfort for tropics is at 25.8º C to 27.1º C with humidity levels of 71.53 %. According to Gupta *et al*. (2020: 72), ASHRAE Standard (2013) states that relative humidity should be maintained between 30 % and 60 %. The present study revealed that humidity levels were higher than 65% across all kitchen zones. Hence, a dehumidifier is necessary to take excessive humidity out of the air especially in humid, summer weather (Koncius 2018: 1).

iii. The characteristics of workers near stoves must be integrated into the humidity management plan.

In a statistical model, race (ethnicity), mechanical ventilation devices, physiological and psychological symptoms of heat stress predict humidity near stoves.

A mathematical model derived in section 8.6.3 to predict humidity near stoves is affected by worker characteristics such as the height of worker and worker shift. Moreover, worker shift as in section 7.2.8 indicated that the degree of heat exposure in the kitchen is influenced by the worker shift depending on the mealtime. With regard to the influence of height (m) of chefs, higher humidity is experienced by shorter chefs than taller chefs; this is because a short chef is closer to the stove height. More than 52 % of kitchen workers were <1.60 m tall and almost half (48 %) of them complained about humidity, although no significant correlation was achieved. Simone *et al*. (2013: 1005) similarly found higher levels of humidity at the kitchen worker waist height that reduces as head height is approached. Pei *et al*. (2019: 8) state that the breathing zone is at a height of 1.2 m above the floor.

From the model in section 8.6.6, it can be derived that the heat around stoves has a positive relationship with the presence of ovens and dishwashers in the kitchens. The relationships with air-conditioners and domestic fans in Table 8.13 (page 229) indicate that the greater the number of cooling equipment, the lower the heat experienced near stoves. The most common physical symptom of heat in kitchens is heavy sweating which is associated with psychological symptoms such as the use of foul language. Heat-related illness (Table 7.24 page 180) includes physical symptoms and emotional trauma (Doerr 2019: 3) and as per Thermopro (2019: 2) humidity affect sweating.

iv. Heating ventilation and air conditioning and extractors must account for the prevalence of gas-fuelled cooking equipment

Gas cooking appliances will increase the moisture generated, as water vapour is a by-product of gas combustion (Parrott *et al*. 2003: 1). The use of gas in section 7.5.3 and 8.6.4 illustrated raised relative humidity levels in the kitchens. The highest mean relative humidity values of 59.28 % and 58.62 % were obtained in cooking areas near gas grillers and gas stoves with trimmed mean values of 52.37 % and 51.30 %, respectively. Combustion products from the natural gas used for cooking release a high quantity of water vapour that contributed to high indoor humidity (Kim *et al*. 2018: 1).

v. Establish protocols for special instruction to new and existing staff on behavioural adaptation to cope with humid heat.

It was observed that kitchen workers stand near the air-conditioner or fan; step out of the kitchen, move to the back door where airflow helps cope with humid heat and or take a short break. The most common behavioural adaptation by workers was to drink cold liquid (94 %). Kitchen workers are encouraged by head chefs and kitchen managers to drink water to stay hydrated. Behavioural modification to cope with humidity includes the use of fans and air-conditioners by kitchen workers (Table 8.21). Almost 35 % of head chefs report that workers took a short break or stepped outside to get respite from the thermal discomfort (8.8 %). Section 8.7 indicates that other strategies used by kitchen workers included going towards a cooler, sitting in the cooler, putting head inside the chiller, keeping the back door open and pouring water on their heads. All these adaptations resonate with those of Indraganti *et al*. (2015: 292) and Balakrishnan *et al*. (2010: 3). According to the University of Birmingham Health and Safety fact file (2006: 1), health and safety precautions must not be relaxed; the wearing of the correct protective personal equipment must persist despite the extreme temperature. Education and awareness-raising must lead to behaviour modifications and practices (WHO 2020: 1). These may, for example, extend to first cooking on back burners to increase the removal of cooking emissions, effectively reducing humidity (Singer and Stratton 2014: 23).

11.4.4.3 Heat

i. The design of stove ranges must account for the kitchen worker gender, age and race.

Section 7.3.2 designates a factor loading of 0.780 for males to cope better than females with other individual factors demonstrating that gender plays an important role in coping with the heat. Alshaikh and Alhefnawi (2020: 391) found that males are more sensitive to hot temperature than females. Even though females cope with humid heat better (Lundgren *et al*. 2013: 8), men cope better with radiant heat generated from grillers and ovens. The variation in the average BMR and body heat production between men and women explains that there is a difference in environmental temperature required for comfort between males and females (BBC News Magazine 2015). According to Devlin (2017: 2), women have a lower BMR than men and the skin temperature for women tends to be lower. In general, females are more sensitive to cold conditions (Van Hoof *et al*. 2017: 124).

Similarly, workers older than 60 years cannot cope with the heat in kitchens (Better Health Channel 2020: 1). Hansen *et al*. (2011: 4724) contend that the thermoregulatory abilities of older persons may be compromised due to age or disease. The elderly are comparatively susceptible to thermal environmental conditions outside the 'common' temperature range (Van Hoof *et al*. 2017: 123). Hence, improved indoor environmental design regarding the thermal environment will enable older staff to cope with the heat.

Improved indoor environmental design regarding the thermal environment will enable elderly staff to cope with the heat. The indoor air quality in kitchens 3, 6, 7 and 14 in Table 8.1 (section 8.2.2) was better than other kitchens as the temperatures did not exceed 30° C due to the presence of good natural ventilation from the ocean breeze, perforated perimeter supply, air-conditioners and air curtains. These kitchens also had large unoccupied spaces, so permitting airflow in different kitchen areas. Some races of workers such as Whites and Mixed-race groups can cope with higher heat in kitchens if the indoor environmental design concerning the thermal environment can be alleviated to enable staff to cope with the heat in the kitchen. In this regard, Farnell *et al*. (2008: 238) confirms thermoregulatory differences between Caucasians and African Americans.

ii. The prediction of heat near stoves must factor in the linear combination of the type of kitchen, staff job position, years of employment and worker shift.

Section 7.6.3 of the primary study revealed that kitchen staff perception of heat near stove = 35.341 + (-0.103 x job position) + (-0.091 x years of employment) + (-0.403 x worker shift) + (-0.722 x type of kitchen).

The relationship with job position indicates that the higher the position, the lower the heat experienced near stoves. There is strong evidence to conclude that the variables are negatively associated. About 47 % of head chefs strongly agreed that years of employment played a strong role in coping with the heat and a negative association with kitchen staff perception of heat near the stove is seen. Table 7.6 indicates that 66 % of the kitchen workers had a day shift and worked full-time, leading to higher heat adaptation from stoves and an inverse relationship. Light duty kitchens have lower ambient temperatures and hence an inverse relationship is expected (Table 7.13).

Extreme heat-generating equipment is among the perils that cooks navigate in their daily work environment (Laiskonis 2016:1) as in the case of a prep cook or line cook. Contrarily, most executive chefs primarily handle administrative tasks and may spend less time in the kitchen (Truity 2017: 1).

Flouris *et al*. (2018: 521) report that at the end of a work shift under heat stress, 35 % of the workers experienced occupational heat strain as the degree of heat exposure in the kitchen depends on the worker shift. Worker shift as explained in section 7.2.8 indicates that the degree of heat exposure in the kitchen is influenced by the worker shift depending on the meal-time. Section 8.5.4 indicates that the humidity levels near stoves in the kitchen also vary with work shift.

iii. Specific aspects of worker physiology and the physical structure of the kitchen must inform the management of worker experience of heat near stoves.

The result of factor analysis expects that gender plays a vital role in coping with the heat. Primary predictive factors revealed in statistical analysis (Table 7.18 page 174) were the kitchen height, symptoms of red face and sweating, discomfort index, staff/space ratio and state of the uniform.

Consistent with Ravindra (2015: 56), factor analysis anticipates that gender is integral in coping with the heat in Table 7.8. Also, Table 7.18 conveys that the kitchen height along with the staff - space ratio also emerge as factors affecting worker experience of heat near stoves in section 7.5. They collectively raise the sweat rate and the uniform becoming excessively wet. Lotfabadi and Hançer (2019: 2) add that increasing ceiling height leads to an improved sense of thermal comfort in summer, particularly in hot and humid climates. High ceilings were observed in 12.1 % of the sampled kitchens. Medium-duty kitchens were found to have the highest workspace ratio of 10.16 which is a high-density workspace per Simmons (2019: 1).

When left unchecked, per section 7.5.2 the experience of heat near stove = – 6.795 + (– 2.162 x symptoms red face) + (0.446 x Discomfort Index). The experience of heat near stove has an inverse relationship with symptoms of a red face. As a worker gains experience working in a hot kitchen, adaptation to heat leads to fewer symptoms of heat strain. Masuda *et al*. (2019: 38) claim that adaptations to heat by workers may be underappreciated.

iv. The management of worker experience of heat in the kitchen must be informed by specific personal factors and work status of kitchen workers.

Section 7.6.2 indicates that kitchen heat experienced by chefs was found to be associated with job position, work shift, type of kitchen load, years of employment and race. Except for the two factors-job position and work shift, the other factors are explained in the ii above.

The job position of a kitchen worker seems to influence the ability to cope with the heat in the kitchen. This is confirmed in the observation that most pastry chefs worked with ovens, and the grillers and pizza chefs were exposed to extreme heat in kitchens while working with ovens that operate at 371° C. Dishwashing and cleaning assistants are exposed to humid heat that adds to thermal discomfort (Table 7.22 page 178). Extreme heat-generating equipment is among the perils that cooks navigate in their daily work environment (Laiskonis 2016: 1) as are workers who occupy prep cook or line cook status.

Flouris *et al*. (2018: 521) report that at the end of a work shift under heat stress, 35 % of the workers experienced occupational heat strain as the degree of heat exposure in the kitchen depends on the worker shift. The present study confirms in section 7.2.8 that the degree of heat exposure in the kitchen is influenced by the worker shift depending on the meal-time.

Almost 47 % (f=16) of head chefs strongly agreed that work experience played a substantial role in coping with heat; also, the years of employment contributes to acclimation to heat. Table 7.4 indicates that work experience varied from three months for a trainee chef to 35 years for a 60-year-old chef. Acclimation may, according to Lundgren-Kownacki *et al*. (2019: 10), be induced by a systematic heat exposure regime, a view shared by Singh *et al*. (2016: 11) to adapt to the workplace prior to taking up the jobs in kitchens. Acclimation among experienced chefs and kitchen workers helps to cope better with heat stress in kitchens.

Farnell *et al*. (2008: 238) posit that race influences an individual's ability to thermos-regulate was shared by 37.5 % head chefs and kitchen managers (Table 7.7). This observation has the potential to be influenced by an interest in physical fitness. Regarding physical fitness, 57 %, 50 %, 49 % and 39 % of the Black, Asian, Mixed-race (Coloured) and White respondents respectively, showed low physical fitness levels indicating lowered tolerance to heat. Overweight and obese kitchen workers may experience higher discomfort levels as Habibi *et al*. (2016: 1) observe a higher risk of heat strain in overweight subjects, and Parameswarappa and Narayana (2014: 865) caution that the risk of heat illness increases with excess body fat. However, 10 %, 6 %, and 5 % of the White, Asian/Black and Mixed-race (Coloured) respondents, respectively indicate a higher level of physical fitness, indicating higher tolerance to heat (Table 7.9 page 163).

Consistent with EFA, 37.5 % (f=12) of respondents strongly agreed that race has the highest level of influence on coping with kitchen heat and 20.6 % (f=7) strongly agreed that fitness has the highest level of influence on coping with kitchen heat (Table 7.8). An odds ratio of 1.45 indicates that each female worker assumes she is 1.45 times physically fitter than she actually is, which helps the female worker to cope with heat better as this has a positive psychological effect (Table 7.9 page 163). Rupp *et al*. (2020: 813) find that a psychological variable (thermal disposition) should be considered when addressing individual differences in thermal comfort.

v. Maintain air velocity to 0.5 m/s in all areas to sustain lower temperatures.

The present study indicates that there was no airflow in 12 % of kitchen zones of the sample frame (Table 8.3 page 205). Although 60 % of the kitchens had an adequate airflow rate of 0.5m/s, it was uneven in some areas. The mean airflow measured between 0.08 m/s to 0.47 m/s in dishwashing areas and corridors, respectively. The range from minimum to maximum across all kitchen work areas varied from 0.00 to 2.5 m/s (Table 8.3); the present study recorded a range of 0.06 m/s to 0.42 m/s in casual and quick-service restaurants. About 56 % of the workers complained that ventilation was inadequate in the kitchens with airflow rates ranging from 0.0 to 0.63 m/s.

While Li *et al*. (2019: 505) confirms that indoor air distribution determines indoor air quality and human comfort, minimum airflow of 0.5 m/s in every kitchen zone becomes necessary (Timerbaeva 2010: 50).

vi. The benchmark for the design of kitchens must be guided by ceilings no lower than three meters.

In the present study, ceilings higher than 4 m in three kitchens helped to keep kitchens cooler. As the temperature range of human comfort is small, variations however subtle may cause thermal discomfort to users (Guimarães *et al*. 2013: 76). The sampled kitchens had a mean of 3.03 m with the lowest ceiling height of 2.41 m; a median of 2.96 m; and a maximum of 4.17 m. More than 30 % of the kitchens had ceiling height less than 3.0 m. Almost 78 % of these kitchens had lower air movement as kitchen workers complained about stuffiness. In spite of the presence of cooling devices in 67 % of these kitchens, airflow was limited due to poor volume of kitchens with low ceiling heights. A minimum height of 3 m in kitchens would permit greater airflow and is ideal for commercial kitchens. Guimarães *et al*. (2013: 75) show that in tropical countries, for every 20 cm reduction in ceiling height, the temperature increases by 1° C. A kitchen height of 3 m is suitable for better ventilation (Manshoor *et al*. 2014a: 5), so advancing improved heat management.

Stoakes *et al*. (2011: 373) posits that the main reason for high ceilings is to facilitate airflow in summer. Lotfabadi and Hançer (2019: 2) add that increasing ceiling height leads to an improved sense of thermal comfort in summer, particularly in hot and humid climates; with higher ceilings, the air volume is greater and creates more air movement.

vii. The height of work counters must account for ethnic differences.

The height of kitchen workers in Table 7.1 varied from 1.45 m to 1.83 m with an average of 1.59 m. This suggests that South African kitchen workers are shorter and feel increased thermal discomfort in kitchens as Pei *et al*. (2019: 8) state that the breathing zone is at a height of 1.2 m above the floor. Simone *et al*. (2013: 1005) similarly found higher levels of heat at the kitchen worker's waist height that reduces as head height is approached.

More than 52 % of kitchen workers were <1.60 m tall. Chefs with less than average height find 0.81 m (32″) to be a comfortable work-surface height (Table 7.1). Regatta (2019: 3) recommends that an ergonomically correct countertop height varies from 0.762 m (30″) for a 1.21 m tall cook to 1.07 m (42″) for a 1.82 m tall cook. Shorter people find the standard counter height of 0.91 m (36″) too tall to work comfortably in section 8.5.4. A shorter chef feels hotter near stoves; this is because a short chef is closer to the stove height.

viii. Cooling devices along with extractors must be installed in kitchens.

Tables 8.14 and 8.15 indicate that there were significantly more respondents who indicated that there were very few air-conditioners and industrial fans ($p < 0.05$). Almost 33 % of head chefs responded that it was inadequate and 41 % of kitchen staff found the thermal environment uncomfortable. Air vents (24 %) and air-conditioners (18 %) helped mitigate staff discomfort from heat and humidity with cool air. In some kitchens, these ventilation modes per Table 8.1 were found to be inadequate to cope with the heat and fumes. During summer months and especially daytime, heat and humidity were high as cold air was not pumped into kitchens lacking air-conditioners or diffusers (Alam *et al*. 2019: 4). Matsuzuki *et al*. (2013: 171) find it necessary to install air-conditioners in different areas in hospital kitchens to improve the kitchen environment. Fans are further advanced to ensure the comfort of kitchen workers (Die-Pat 2016c: 2).

xi. Use of electric and induction stoves reduces thermal discomfort.

Section 7.5.1 indicates that even though 58.5 % of chefs preferred gas stoves, the excess heat produced from the open flame and discomfort increases heat stress; 88 % of kitchens adopted non-pressure or low-pressure gas stoves. The cross-tabulation (Appendix 24) between the kitchen worker's preference for an electric stove and maintaining a comfortable lifestyle was found to be statistically significant. Just over 41.0 % of the workers felt comfortable cooking with electric stoves, however, they had actually never cooked with gas. Table 7.14 indicated that electric appliances tend to be used less frequently contributing to a minor share of heat stress symptoms.

Section 8.5.3 indicated that the use of electricity instead of gas for cooking produces a healthier and comfortable environment. Accordingly, Leitner and Kajtar (2018: 30) state that a gas stove is considered to be a source of heat. Almost 74 % of the energy produced on an electric range is transferred to food, compared to about 40 % on a gas range (Schwartz and Vila 2020: 3) whereas induction cooktops transferred up to 90 % of the energy to food.

11.4.4.4 Acoustics

i. Specific personal factors of kitchen workers must be accounted for in the acoustic design of kitchen workstations.

The noise experience in kitchens is affected by gender, age and race of kitchen workers. The results in section 9.2.3.1 indicate that whilst reaction to stove noise is affected mildly by the age and race of the worker, a moderate effect is observed by the gender of the kitchen worker. The reaction to stove noise (Table 9.4) seems to vary widely between males and females. Lin *et al*. (2011: 109) draws attention to the odds of hearing loss among Black persons are substantially lower than in White individuals. However, there is inadequate literature on gender, age and race regarding kitchen noise.

ii. The variation of food production activities must be accounted for in the acoustic design of kitchen workstations.

The noise levels in kitchens are affected by food production activities. Noise from equipment generated due to food production activities in the preparation area, the ringing of orders and cooking areas were specifically found to add to the din in the kitchen. Farber and Wang (2017: 6) contend that noise levels should not exceed 75 dBA. However, the preparation area in three kitchens recorded high noise levels >80 dBA due to potato peelers and salad dryers. The ringing of orders recorded 82.5 dBA in the holding area. Noise levels across cooking areas ranged from 53.20 dBA to a high of 75.26 dBA. The collective activities in food preparation and cooking areas produced excessive noise levels. According to the South African National Standards 10103 (2008: 12-13), maximum levels for ambient noise recommended in kitchens is 55 dBA. However, the mean values in different areas of sampled kitchens ranged from 43.2 dBA to a high of 76.35 dBA.

iii. The kitchen design must take cognizance of the cuisine and scope of menu items in different action zones.

Table 9.2 indicates similarity in the noise levels in the receiving areas across all types of cuisine. Differences in other work areas are sizable and vary according to cuisine and scope of menu items. For example, kitchens with Indian cuisine in Table 9.3 emitted louder noise levels in preparation areas. Similar variation occurs in stoves in Oriental Chinese and Thai cooking (84.75 dBA). The noise emission from Chinese cuisine kitchens is known to reach a mean of 87 dBA (Yu and Wong 2002: 1). Additionally, the recorded kitchen noise in fast-food kitchens, the fryer and griller in fusion cuisine kitchens and the dishwashing noise in the continental kitchen were much higher than the rest of the sample frame. Yang *et al*. (2021: 2) observed that the airflow rate of kitchens required by the Chinese standard is higher than that of ASHRAE standard and England Building Regulations. Chinese standards stipulate the maximum and minimum exhaust airflow based on several factors including Chinese cooking habits. Nevertheless, criteria for advance commercial kitchens in subtropical locations for the well-being of food production workers are not available. Page (2019: 11) identifies that heat stress is the most neglected occupational hazard in kitchens of subtropical countries.

vi. Perception of acoustic design in kitchens must consider the type of food service operation.

As per Simone *et al*. (2013: 1002), the food service establishment classified as casual restaurants, institutional restaurants or quick-service restaurants requires different kitchen activities such as preparation, cooking and dishwashing. Hence, the noise levels can be higher in fast-food restaurants due to pinging. Preparation and holding areas have higher noise levels from ringing/beep and serving customers (Table 9.2). Reddit (2014: 1) expresses that in quick-service restaurants, aside from the ringing of orders, the fryers and the grills also beep when the food is done. The warming trays have timers set to the number of minutes that the quality of food stays good. The kitchen workers in fast-food restaurants justify the beep noise to be loud and although annoying, it is necessary for drawing the attention of staff.

Casual kitchens have higher dishwashing noise due to manual dishwashing. Quick-service restaurants have comparatively lower levels of dishwashing due to the use of disposables. Gallego-Schmid *et al*. (2019: 417) observe that there is an increase in consumption of takeaway food in single-use containers worldwide.

More than 58 % of institutional kitchens have dishwashing facilities reducing clanging of dishes, although dishwashing machines also add to the noise in kitchens. Almost 43 % of quick-service restaurants and 15 % of casual restaurant kitchens had dishwashing machines. Casual restaurants had higher noise levels of 76 dBA, lower than Green and Anthony (2015: 2) with levels of 105 dBA in locally owned casual restaurants. Hear-it (2019: 1) reports that noise levels vary from 67 dBA to 80 dBA in school cafeteria kitchens. Cisca (2015: 3) observes that open-plan kitchens in casual, quick-service restaurants and fine dining kitchens do not contain noise levels.

v. A scheduled maintenance system designed for corrective repair and the consistent operation and reliability of equipment must be prescribed.

The noise from refrigerators, freezers, air-conditioners, convection ovens, pressure LPG stoves, and extractors were acceptable or above acceptable levels in some kitchens which may be mitigated by scheduled maintenance. The ranking of noise in section 9.2.4 indicates that the equipment needs maintenance for reduced noise production. Fox (2019: 1) attributes different noise levels for kitchen appliances from 70 dBA and downward for an extractor. However, noise from extractors in kitchens 14, 16, 18, 25 and 28 exceeded 70 dBA. The exceedingly high noise levels in kitchen 25 was due to the exhaust fan requiring maintenance.

Whereas an estimated 88 % of the equipment was in good repair (Figure 9.7), 5.9 % of the head chefs in section 9.5.1 claim that all equipment was not in good repair and a further 11 % contend that their kitchen equipment is in a poor working condition. The ranking of noise in section 9.2.4 indicates that the equipment needs maintenance for reduced noise production. Serfozo (2018: 1) confirms that the causes of noise may substantially be attributed to improper maintenance. Garbuzova (2017: 1) further found that scheduled maintenance of fryers and boilers will reduce their noise emissions.

11.4.4.5 Lighting

i. The optimal balance of natural light and skylights must be derived for every kitchen area.

The observed challenges in the sample for optimal light balance include insufficient light and poorly distributed light. The presence of natural light influences daytime lighting in all kitchen areas (Table 10.1). There is a lack of theory development in empirical research on the optimal balance of natural light and skylights in commercial kitchens in subtropical locations. Velux (2017: 1) recommends windows as sources of illumination and sun provision in buildings for promoting healthy indoor environments. Sonae Arauco (2020: 1) adds that possibilities for more natural light into an internal space include installation of skylights and glass sliding doors.

Preparation area lighting = 108.121 + (134.058 × Natural Light) + (-104.870 × Skylight). As the preparation area requires lighting levels of at least 300 lux (Velux 2017: 1), the bar for adequate lighting is accordingly set. Notably, the use of sunlight in kitchens is an important criterion in designing lighting using the predictive potential of this equation. The modelled predictor indicates that for every unit increase in the skylight, a -104.870 unit decrease in lighting needs in the preparation area is predicted for good vision holding all other variables constant. One of the most positive aspects of having a skylight is that it brings extra daylight into a room; increase in natural light from skylights reduces the use of artificial lighting and electricity (Reggev 2017: 3). Yazıcıoğlu and Kanoğlu (2016: 35) recommend at least 8 % of the total area of an open/closed kitchen must be an area allocated for windows or skylights. Whenever the only window in a room is a skylight type window in the top of the room, the total window area of the skylight shall equal at least 15 % of the total floor area of the room (City of Milwaukee 2020: 571).

ii. Stringent cleaning routine

Procedures for clean-up of all sources of kitchen lighting must be consistently maintained. Soiling leads to inappropriate measures of sunlight, fluorescent light and incandescent light that can cause uneasiness and headaches (Bailey 2019: 1) and eyestrain (Denny Vision 2019: 2). Practices to assure clean light fixtures that advance lighting consistency in Table 10.8 (page 278) are indispensable to comfortable and effective illumination. In this context, the study found an association of headaches with a preventable cause, clean lights and fixtures expressed in the equation: Lighting in preparation area = (- 881.86) + (92.341 x headaches) + (112.088 x clean lights and fixtures). The inverse relationship here with the constant reflects that lower levels of lighting are needed in preparation areas when the lights and fixtures are clean and bright lights cause a headache.

Green Seal (2014: 12) recommends that lighting fixtures, diffusers and lamps must be cleaned once a month. Access to natural ventilation means dirty lamps and fixtures. Selection of fixtures that allow airflow instead of through the fixture past the bulbs minimises dirt accumulation. (Los Alamos National Laboratory Sustainable Design Guide 2018: 86). However, 18 % of the kitchen workers in the present study claimed that they have never observed cleaning of light bulbs and fixtures. Seventy-one (71%) of the kitchens had clean bulbs and almost 66 % of kitchens had clean fixtures. However, the cleaning of lighting systems was an annual program in 70 % kitchens.

iii. Lighting design must take cognizance of the presence and extent of contrast in kitchens.

More than 9.0 % of the kitchens had slight contrast in some areas and 76.5 % of the head chefs (Figure 10.5) agree. Table 10.14 (page 288) indicates that the fewer the staff (3.03 %) who complained about lighting contrast in the kitchen, the higher the incidence of adequate lighting in kitchens and staff being happy about it. The observational study further revealed that 9.1 % of kitchens had contrast with chi-squared values of 66. Morton (2016: 18) claims that inappropriate lighting can lead to contrast.

Using exploratory factor analysis for contrast, there is strong evidence that the variable contrast and lighting in preparation and cooking areas are closely associated. In addition, section 10.6.2

indicates that adequate lighting in preparation and cooking areas affects the degree and presence of contrast in kitchens. According to Health and Safety Guidance 38 (1997: 13), strong shadows on the task area or reduced contrast of task can be solved by providing local or task lighting. Contrast is a crucial factor in visual comfort (Advanced Glazings Ltd 2020: 2).

iv. Lighting design must take cognizance of the existence and magnitude of natural light in kitchens.

Almost 15.2 % of kitchens had optimal lighting levels in kitchens due to the influx of sunlight. Most areas in kitchens met the criteria for 300-500 lux as recommended by SANAS, OSHA, WHO, CIBSE, BOSH and Australian Standards. These commercial kitchens are well-designed with proper implementation of lighting for the staff to perform their tasks of food preparation, cooking, presentation and cleaning efficiently and safely. At the same time, reflections and glare were absent. Kitchen 27 does not use artificial lighting most days during daytime unless the sky is grey/overcast. Due to the location of the kitchen in the commercial complex, kitchen 4 had bright artificial lights and no windows. The presence of glass walls in the front and open back doors flooded different kitchen areas with sunlight depending on the layouts. Table 10.3 (page 266) indicates lighting levels (lux) in kitchens with optimal natural light from doors, windows, glass walls and the presence of skylight in the ceiling.

The relationship between artificial lights and natural lighting is important when installing commercial kitchen lighting. RH Homes (2020: 4) declare that be it natural light or artificial lighting, brightness is experienced subjectively. For the best balance, at least three sources of light should be available in every space including sunlight. Lighting measures derived by a light meter indicated that five kitchens (12 %) enjoyed optimal lighting. Of these four were lit by ambient lighting, task lighting and sunlight.

Dimmers change the balance between artificial light with natural light in the day (Better Homes and Gardens 2020: 3). The magnitude of artificial lighting with respect to daylight in the kitchens can be transformed by dimmers. However, dimmers were not installed in any of the sampled kitchens. The Australian Government (2010: 10) observes that the successful integration of daylight and electric light indoors will depend on the achievement of a satisfactory brightness distribution and not on the balance of daylight and electric light illuminances.

11.5 Recommendations

The following recommendations for practice as informed by research and evidence that suggest prompt actions to be taken in commercial kitchens, particularly in Durban area. These assist in worker well-being.

11.5.1 Ventilation

i. Kitchen fenestrations are to be placed on the windward side in a building in a crowded city or placed on the leeward side in an open space for natural ventilation. This supplements mechanical ventilation, moreover, windows strategically designed and left ajar will improve natural ventilation in kitchens.

ii. The adaptation of ventilation systems as per International Mechanical Code classification of extractors based on the heat load in kitchens and the required exhaust flow rate, will help to maintain acceptable humidity and CO_2 levels in kitchens. The change will alleviate breathing problems, reduce odours and particulate matter in the air, reduce mould growth and improve thermal comfort. Monitoring oxygen levels in kitchens is another important factor that indicated that cabon monoxide levels are within safe limits.

iii. Ventilation rates in commercial kitchens should be based on the load generated by the kitchen equipment and accounted for in building codes and guidelines. Also, the periodic preventative inspections of hoods on heavy-duty operations could be a workable way to reduce risks. Good workmanship of design and installation of extractors is essential.

iv. Consistent with International Mechanical Code, 507.1.5, the present study maintains that exhaust outlets be installed to optimise the capture of particulate matter. Each outlet should not serve more than a 3.658 m section of the hood**.** It is recommended that these be incorporated in South African municipality by-laws. Re-classifying kitchen extract systems as local exhaust ventilation would mean they are subject to more stringent regulation and inspection, which improves their ability to remove harmful fumes and organic compounds from the air. The management maintains a planned schedule and regularly follow up to check on the efficiency of the ventilation system and exhaust rate.

v. Besides the kitchen workload, ventilation systems to be designed according to shape and layout of the kitchen; the cooking equipment used-based on cuisine; the number of kitchen staff; ease of maintenance and energy efficiency. To attain optimum exhaust operation, modern kitchens often make use of variable speed drive fans. These may use hood thermostats to assess the ventilation needs of a kitchen at a specific time. Since they generally run slower outside of peak times, they still maintain effective air exchange while cutting energy costs significantly.

vi. Specific information on the seating capacity of the restaurant, maximum food production capacity, number and type of equipment installed, expected heat production from cooking appliances, maximum power of cooking appliances, the volume of the kitchen space, number of staff members working in the kitchen per shift to be estimated while installing a hood. As long as the hood covers the cooking area, the extractor fan is selected for the size of the hood; this design concept without considering other factors will cause ventilation inadequacy.

vii. Hard-wired CO_2 detectors designed for commercial catering environments should be used. These give an audible alarm and are linked with an automatic gas shut off system that is fail-safe and requires manual intervention to restore the gas supply. Institution of Gas Engineers and Managers (2015: 7) and section 8.5.2 prove that installing CO_2 monitors in the kitchen will help to determine the discomfort levels, oxygen levels and adequacy of a ventilation system.

viii. The frequent filtering of oil and adding fresh oil to frying oil will improve the quality of oil and reduce fumes as reported in section 8.4.1 and by Zhao *et al*. (2019: 1953). Monitoring frying oil safety by adopting at least one method of testing oil quality to be made mandatory by the municipality by-law will help to control the use of reheated cooking oil. Test strips for free fatty acids, p-anisidine value or total polar compounds must be evaluated. Regulations on frying oil safety and systematic monitoring of oil quality help to control the use of reheated oil that will reduce emissions in the kitchens.

ix. Installation of a well-designed mechanical ventilation system is necessary to prevent mould growth that can cause sick building syndrome and reduce the quality of indoor air. Mould growth was observed in more than 5 % of the kitchens due to excessive humidity and wet floors near dishwashing areas. About 51 % of kitchens had 60 % or more humidity levels in one or other kitchen zones but not in all the areas although it was high enough to encourage mould growth on kitchen walls and floors.

11.5.2 Heat

i. Male workers cope better with heat in kitchens and are suitable for stove exposure. Even though men cope better with radiant heat generated from grillers and ovens, females cope with humid heat better. Female workers can be placed at stations where stove exposure is minimum or indoor environmental design regarding the thermal environment can be upgraded to enable female staff to cope with the heat in the kitchen.

ii. The benchmark for design of kitchens by increased air velocity in all areas and maintain lower temperatures by installing diffusers, perforated perimeter supply and or air-conditioners should be improved. Currently, the standards necessitate the use of extractors, however, it is not compulsory to install cooling devices in hot kitchens.

iii. The job position of a kitchen worker seems to influence the ability to cope with the heat in the kitchen. Workers can be rotated from low stove exposure stations to high stove exposure stations gradually to develop heat acclimatisation. Though an ideal situation, if not feasible, cooling devices can be installed to reduce heat stress.

Work shift to be rotated to provide an opportunity for workers to experience high and low heat during peak periods and different shifts. Continuous stove exposure of workers will reduce, and newly employed workers will develop heat acclimatisation.

Similarly, older workers and female workers to be moved to stations with lower stove exposure according to their skills to reduce ill-health.

Alternately, a perforated perimeter supply can be installed near high heat appliances used for grilling, frying and baking sections to reduce the effect of radiant heat near the equipment, promoting lower heat illness and better working conditions.

Workers from other races such as mixed-races (Coloureds) and Whites (Caucasians) with lower adaptation to heat can cope with the heat in the kitchen if the indoor environmental design regarding the thermal environment can be elevated to enable staff to cope with the heat in the kitchen.

iv. Since equipment such as ovens, boilers and steamers, gas stoves and fryers contribute to substantial heat in the kitchen, they should always be installed under Type I or Type II hood-as per heat load specifications.

v. Longer tenure, experience with warm weather, heat acclimation with service during peak periods, and practice a comfortable lifestyle at home by kitchen workers to improve acclimatisation and prevent heat illness.

vi. The appropriate measures are to be instituted to assure that uniform are worn in the kitchen. Newer heat resistant comfortable uniform to be provided for kitchen workers. These to be supplemented by newer methods of keeping cool such as the use of cooled wipes or towels help to keep workers' body temperature cooler.

vii. Improve the standards for the design of kitchens with higher ceilings and maintaining lower staff-space ratio will reduce discomfort, flushing, sweating and wet uniform from sweating. Increasing air velocity in all areas and maintaining lower temperatures by installing diffusers, perforated perimeter supply and or air-conditioners will alleviate symptoms of discomfort. The improved indoor environmental design regarding thermal environment will enable staff to cope with the heat in the kitchen especially during peak periods and alleviate symptoms of heat stress.

viii The practice of cooking of suitable foods in advance can reduce the heat generated from the stove during peak periods.

ix. A heat-rejecting film that could reflect 70 % heat from sunlight and cool a building while still letting in a good amount of light can cover kitchen windows.

x. Installing a thermal work limit index calculator could indicate to staff to cool off. These indices are a better tool for evaluating heat stress among kitchen workers who perform their tasks in warm and humid environments. As thermal work limit index is better than wet bulb globe temperature in discriminating acceptable and unacceptable levels of heat stress and can be more useful in planning intervention strategies and assessing their effectiveness. Ahmed *et al.* (2020: 179) recommend that in the workplace with the wet-bulb globe temperature index, a complimentary assessment by thermal work limit be used.

xi. Maintaining an integrated harmonious environment at work of basic factors such as temperature, noise levels, amount of space and workspace cleanliness will provide worker comfort. In addition, proportional factors such as air quality, amount of light, visual comfort, ease of interaction, and maintenance will create well-being among workers. However, bonus factors such as daylighting, external view through windows and individual controllability of indoor environments when provided could improve staff overall satisfaction at work.

xii. A combination of approaches for adaptation to heat in kitchens is recommended. Comfortable uniform, simple hairstyles, minimum make-up, pacing work during summer, maintaining optimum kitchen temperatures, humidity levels and airflow.

xiii. Kitchen workers to arrive hydrated at work and prevent perpetuating a cycle of dehydration. Water-electrolyte balance can be maintained among workers by facilitating fluid consumption such as providing drinking water and monitoring cool drinking water-1 cup every 20 minutes or drinking water 5 L/day. In addition, drinking cool drinks and lemon juice low in sugar will assist in hydration.

xiv. It is recommended that a broader diet and lifestyle structures are implemented along with heat stress awareness training for workers. Pre-placement screening of susceptible workers, using proper clothing, resting in cool places during breaks, providing shielding from radiant heat, training staff on symptoms of heat stress and pacing will help to prevent heat illness. Training on heat stress, improving ventilation, loose-fitting clothing and breaks during work are recommended. Chefs from different restaurants have different strategies such as install air-conditioning; spend a long time in walk-in refrigerators to cool-off and wrap cold damp towels around their necks.

xv. The efficacy of kitchen extractor system in regulating air quality, heat and humidity must receive greater attention in the kitchen design decisions. Further to staff complaints of summer heat and humidity, outside of peak periods, nine restaurants were found to have CO_2 levels higher than 1000 ppm near grillers, tandoors and stoves.

xvi. Specific rules and guidelines be developed for working in high-temperature workplaces and monitor the implementation of such regulations. Organize training programs about prevention and control of heat-related complications for workers and employers. All workers to pass heat adaptability courses before starting their work to prevent the effects of heat stress. Employers to screen kitchen workers while recruiting them to identify those more susceptible to heat.

xvii. It is highly recommended that employment density guidelines for kitchens in restaurants and cafes be prioritised for formulation by the SA Department of Labour.

xviii. Work counters to be modified to accommodate the variation in height considering ethnicities. Shorter people find the standard counter height too tall to work at comfortably. Many people of less than average height find 0.81 m (32″) to be a comfortable work-surface height.

xix. The greater the tenure in the kitchen, better the acclimatisation to heat. Acclimatise female workers and particularly, workers belonging to races other than Indian or African for a longer period to improve their ability to cope with the heat. As per their employment contract, workers can be acclimatised during in-service trainings and or orientation programs. Similarly, newly employed workers without any work experience to be acclimatised for a longer period to improve their ability to cope with the heat.

xx. Worker shift can be rotated to provide an opportunity for workers to experience high and low heat during peak periods and different shift periods. Continuous stove exposure of workers will reduce heat stress from heat acclimatisation and newly employed workers will develop heat adaptation.

11.5.3 Noise

i. Installation of vibration damping sheet on extractor hoods and metal ducting. Reduction of the vibration using damping materials can provide a possible sound power reduction of up to 6 dBa assuming that the other parameters are kept constant. Noise from extractors can be mitigated by regular maintenance and installation of soundproof materials. The soundproofing material deadens harsh noises and blocks sound transfer.

ii. Tables used for preparation with equipment placed on them require an isolation mount. Vibration and noise from small to medium equipment such as salad dryer, hand blender, ice crusher and a coffee grinder will be efficiently absorbed reducing noise in kitchens by placing them on a silicone mat away from a wall. To stop structure-borne noise, heavy equipment can be placed on isolation mounts or pads. To reduce airborne noise from the same equipment, absorber combination acoustical blankets can be used to construct enclosures.

iii. Use of soundproofing material to be made obligatory in the kitchen ceiling. Since changes in structure are not feasible, alterations can be made in the ceiling by incorporating acoustic tiles suitable for kitchens and the addition of sound absorption paint coating on walls can be made. Floor coverings with a high Impact Insulation Class rating help to reduce the impact of sound transmissions to lower levels, thus reducing or eliminating those bothersome noises.

iv. Cuisine requiring elaborate preparation utilising noise-generating equipment necessitates intricate noise absorption arrangements. Noise reduction strategy should be incorporated during the construction stage. Concrete constructed kitchens should have inner structures with softer, more flexible materials, such as wooden studding filled with insulating material and interior wallboard to reduce sound transmission. Sound-absorbing materials such as acoustic tiles on walls can reduce sound transmission. Architectural elements such as built-ins or alcoves can help immensely by breaking up soundwaves.

v. The enforcement of equipment specification and installations protocols compliant with the South African National Accreditation System, South African Bureau of Standards or Occupational Health and Safety Act of 85, 1993 in South Africa will reduce noise levels.

vi. Noise absorption and heat-rejecting film that could reflect 70 % heat from sunlight be coated on kitchen windows. This would not only reduce the building's air conditioning use and costs by 10 % but also reduce noise from lowered use of air conditioners.

vii. Focusing interventions to reduce noise exposures to cooks may be useful in some kitchens, but other food services have dishwashers as the most highly exposed workers. Hence, customizing noise reduction plans in different kitchen areas is necessary. Rearrangement and careful planning of buildings and equipment with the organisation of production lines will have noisy equipment separated from workers as much as possible.

viii. Material used for noise control applications should possess good sound absorption and dampening properties. A novel cheap and biodegradable natural fibre jute can be used for a new noise control application. Applications in kitchen appliances to absorb noise in blenders and grinders can be explored. Similarly, coconut coir fibre applied as porous layer backing during construction can improve noise absorption of walls.

ix. There is a need to sensitize proprietors to the need for kitchen structural design to absorb maximum noise. In the South African context, kitchens acoustic design must account for the particular loudness of staff to decrease discomfort in the kitchen from noise. Culturally, Africans talk louder as a part of their language style in South Africa. Moreover, with the Lombard effect and competitive speech, staff talk louder to be heard and can cause hearing loss to their colleagues. Staff training on speaking in lower tones be emphasised in the instruction manual; staff contract/training sessions/employee rights/ work ethics guidelines. The statement from Ecophon (2010: 3) and section 9.5 support that staff talking in lower tones will reduce kitchen noise levels.

x. Noise reduction of the kitchen environment can be achieved by installing the noise reduction system by triple glazing of walls, cabinetry and flooring of a typical kitchen environment.

xi. As many kitchen workers have shifts that are longer than the traditional eight hours, reduced shift length may be an option to control at-risk noise exposures.

xii. The kitchen smalls such as pots and pans, crockery, cutlery and glassware to be stacked gently to reduce noise in the clearing section, dishwashing areas, storeroom and pantry. Servers/dishwashers to be trained to pace themselves better so they do not end up juggling armfuls of clanking plates. The report by Achutan (2009: 145) and section 9.4 support that reduced stacking of dishes will lower clunking noise from dishes.

xiii. Kitchens should have a square-shaped layout with irregular walls. The rectangular or long narrow kitchen will cause a bowling alley effect and noise will be reflected again and again across walls. A room without parallel walls helps greatly with acoustics, as sound waves cannot build up and bounce back and forth between walls as easily as with non-parallel walls.

xiv. Noise from outside can be prevented from entering kitchens with an outdoor sound curtain barrier wall which is a reinforced loaded vinyl noise barrier and a thick vinyl coated polyester faced quilted fibre glass absorber panels which are cleanable, weatherproof and ultra-violet resistant.

11.5.4 Lighting

i. All glazed windows, doors and glass curtain walls and skylights be kept clean to permit sunlight into kitchens. Solid wooden and metal windows and doors be kept open with the installation of metal bars and security gate to allow natural light into kitchens. During the renovation of kitchens, if possible, adequate window provision and skylight to be incorporated. Similarly, all lamps and light fixtures be kept clean for greater diffusion of artificial light. Cleaning schedules to include lighting fixtures and lamps. Green Seal (2014: 12) and section 10.5 proved that lighting fixtures, diffusers and lamps be cleaned once a month.

ii. Drawbacks in the visual acumen of older kitchen workers is relieved by additional lighting or higher intensity/luminance lamps in workstations (Kunduraci 2017: 185). In support, section 10.4.3 finds that kitchen workers of an average of 60 years of age require more illuminance when compared to a younger person.

iii. Strong lighting in small enclosures be avoided for its increased potential to create glare. More than one source of lighting in each area of the kitchen will prevent glare. Appropriate balanced lighting is the most essential factor in designing for glare-free environments.

iv. Sunlight is the preferred lighting in kitchens and adequate lighting on worktables makes workers more comfortable. From section 10.2 and the South African National Accreditation System that endorses 300 lux, lighting levels in preparation areas is inadequate. A "light duct", daylight duct systems contain a light-collecting unit and light-emitting unit (Iwata *et al*. 2016: 1). Solar tubes that reflect light from the roof be installed through a tube into a kitchen helps chefs to see food and preparation better in dark kitchens (Gibson 2013: 1).

11.6 Study limitations

As with every research activity, this study also has several limitations. These amongst others may mean that while some findings may be transferable to other environments, others will require careful reflection on the context. The limitations of a study are its flaws that could be the result of the unavailability of resources, small sample size, or methodological shortcomings.

A part of the methodology drew on researcher perception for classification of respondent body shape, skin colour and nose shape by the researcher. In addition, extensive researcher contextual experiences were used in estimates of noise classification to continuous, intermittent and impulsive to characterise different noise in kitchens. A unique, more robust multi-part qualitative methodology will have raised trustworthiness, rigor and quality of data.

A small sample size from each of the participating kitchen, may have affected the reliability of survey results. Also, the respondents did not represent all ethnic groups that work at Durban's commercial kitchens. An encompassing saturation sample despite not being possible due to time constraints in the present study, may have provided data that amply embrace and describe phenomenon of interest and address the research questions.

11.6.1 Ventilation and humidity

i. The researcher could not measure the difference in airflow rates according to weather changes. The study was conducted in summer weather conditions where the outdoor temperatures were at its highest, is the worst-case scenario. The effect of weather-induced fluctuations in airflow is not accounted for in the study.

ii. There was inconsistency in peak time measures. CO_2 measures were recorded during meal preparation times in kitchens that were relatively idle with few diners over the data collection period. Besides, some gatekeepers restricted the presence of the researcher during peak periods. The exploratory results may not reflect a picture of trends in all Durban kitchens.

iii. An objective comparison between gas kitchens and electric kitchens and heat stress from gas equipment and electrical equipment could not be made as most kitchens had a combination of equipment using gas and electricity. This reflects the standard practice of most commercial kitchens.

iv. The extraction rate information was unknown to the head chefs and kitchen managers and no disclosure was available from manufacturers, stating that the specification is privileged information. The lack of precise air changes per hour or the extraction rate information limited the quality of air investigation.

11.6.2 Thermal

i. The Thermal Work Limit Index that collectively accounts for relevant measures of dry bulb temperature, wet temperature, bulb globe temperatures, air-speed, barometric pressure and personal factors such as clothing and activity was not computed. The latter was not possible as the measures could not be taken while staff were engaged in their work.

ii. Skin temperature readings were not taken as chefs were constantly in motion during work hours. This would be a better indicator of heat stress among kitchen workers. The level of thermal discomfort on kitchen workers' comfort may be biased and hence the findings of this study to be seen in the light of some limitations in confirming heat stress as the increased skin temperature of staff is an indication of heat stress.

iii. Among the reasons for this study is the dearth of studies relevant to kitchen ergonomic parameters. Hence, a comparative study of different parameters was not possible.

11.6.3 Lighting

iv. Prior studies did not capture, evaluate and measure the impact of lighting on kitchen employee well-being and performance, in order to build an evidence base to support lighting interventions at the workplace. Hence, reference points and inter-study comparisons could not be made with regard to trends.

v. The effect of the type of lighting preferences and illuminance during the workhour schedule of kitchen workers was not investigated. However, the results can be enhanced if eyestrain and light-emitting diode lighting quality, and visual comfort and task performance were studied in kitchens that help to better understand the worker preferences.

vi. Mathematical models for visual comfort are not yet available as an equation needs to be formulated for an easy assessment of worker visual comfort influenced by climatic conditions of diverse geographical areas. A mathematical model for visual comfort could not be derived in this study due to the measurement of a single element of illuminance.

11.6.4 Noise

i. The application of a dosimeter to capture data on the noise exposure of kitchen workers in an 8-hour shift would have enhanced the results of acoustic comfort. In the time that was available, an evaluation of the noise exposure above permissible levels and estimated possible hearing loss over a period not captured. The measure of precise noise exposure will have enabled the researcher to rate and advance informed comparisons from studies of similar sectors.

ii. Mathematical models for noise comfort have not yet been presented as an equation in any published work. An equation captures the relationship between different elements of a parameter that necessitates framing for an undemanding evaluation of worker acoustic comfort. A mathematical model for noise comfort could not be derived in this study due to the non-measurement of noise dose over a shift period.

11.7 Opportunities for future research

The concept of future research addresses unanswered aspects of a research problem. As the present investigation is exploratory, the researcher observed the need for further research in key and novel areas for the investigation of indoor environmental quality in commercial kitchens. These areas spread across both methodological and content-related spaces. An interesting concept may be to apply the current findings in a post-Covid19 world where IEQ and space have taken a new level of importance with optimal ventilation and social distancing among kitchen workers.

11.7.1 Thermal environments in commercial kitchens

i. The existing ASHRAE RP-884 benchmark database (Lucina *et al.* 2018: 502) is in need of informed empirical supplementation to provide a more recent and wider benchmarking database to guide norms for thermal comfort. Studies beyond the existing database for houses, classrooms and offices may be undertaken. The opportunities may further be used to localize these to the South African context.

ii. Creating benchmarks currently unavailable for indoor environmental quality performance in respect of all the parameters interacting together in a kitchen will help compare all deviation in criteria set with adjustments for weather conditions. Although the current study showed no indoor environmental quality associations of the five parameters interacting together, these results are to be interpreted with caution and similar studies will generate a wider body of knowledge.

iii. Thermal comfort is elucidated by many variables including worker metabolism, clothing, indoor air temperature, mean radiant temperature, air velocity and relative humidity. A number of factors that influence the sensation of thermal comfort include cultural and behavioural aspects, age, gender, race, space ratio, and kitchen layout, possibility of control over the environment, user's thermal history and individual preferences. These interrelationships together create mathematical models that will help with the comparative influence of these factors. An improved indoor environmental quality can be derived from better thermal comfort models. These models to provide valuable information on person-environment relationship and factors that affect comfort in a built environment.

iv. There is a gap in thermal comfort studies, particularly in relation to collaborative research. The association with other disciplines in the areas of psychology, physiology, sociology, philosophy, ergonomics, and engineering can be of great value for the development of meaningfully integrated models of indoor environmental quality in commercial kitchens. Such integration has substantial potential for superior practices from improved comprehension of human dimensions.

v. There is a lack of studies in respect of psychological adaptation to heat and other parameters with regard to Africa and South Africa. Whilst, the current study has stated the findings, comparatives do not indicate the deviations and influences of confounding factors.

vi. An investigation into the heat stress among adapted and non-adapted kitchen workers will elicit information on the effect of acclimatisation and thermal comfort. There is a need to evaluate performance loss among physiologically adapted and non-adapted workers in their workplace conditions that will help to alleviate heat stress among workers.

vii. Future studies to make an impact in identifying genotypic differences with diversity in environmental conditions and exposure to hot conditions. The people around the planet from different population groups can be part of the study design. A useful tool for intervention is to establish a relationship between nose shapes and the ability to cope with heat in kitchens. In the same line, establish a relationship between the skin tones and heat adaptation among indoor kitchen workers.

viii. Longitudinal studies on lifestyles and person-centred thermal records of kitchen workers will help to understand adaptive behaviours in different regions. Similarly, to evaluate activities among different cultural groups on coping with temperature changes.

ix. Research the relationship between worker being comfortable with excess hair such as wigs, dreadlocks, and hair extensions, and thermal stress needs to be established. Many male kitchen workers preferred a shaved head to reduce sweating from the head to ease heat stress.

x. An evaluation of a direct association between body mass index and heat stress among kitchen workers will emphasise the importance of fitness.

xi. An investigation of the influence of shift work, as well as job position with regard to heat stress in a kitchen, indicates different thermal exposure. The exposure to heat varies widely among kitchen workers based on shift and workstation allocated.

xii. A study on the impact of the region-specific diet on thermal comfort in the various geographical areas will reveal suitable seasonal food for heat. Cooling foods can be recommended for the consumption during breaks for better heat coping abilities among kitchen workers.

xiii. A framework of recommendations that regulate the standard specific design values for indoor environments that apply to countries that enjoy a temperate climate. No specifications have been put forth for a humid subtropical climate like Durban or Mediterranean climate as in Cape Town or semi-arid cool climate as in Johannesburg. Tropics may necessitate altered levels of comfort parameters authorized in the standards.

xiv. A framework developed on heat control measures that can be performed by (1) designing appropriate infrared heat absorbers around the heat sources to diminish heat stress and heat strain, (2) managerial control by increasing the rest times, (3) using suitable workwear, and (4) using appropriate personal protective equipment where the high heat load is exceeded the standard. These actions would augment the competence of employees resulting in increased quality, enhanced production and hence increased revenues.

xv. It is vital to advance estimates for countries where economies are more reliant on seasons or where current temperatures are higher than in the United States. These countries are also generally poorer and prepared with less infrastructure, and so recognizing realistic and life-preserving adaptations is imperative. The climatic factors that influence health in poorer nations are also many more due to greater dependence on agriculture.

xvi. Additional exploration will contribute to reducing the human health problem of climate change and advise the development of rational climate strategy, which entails knowledge of the health, and other expenses of climate change from around the world. There is a persistent need to develop records and research designs to study additional forms of adaptation, in South Africa and elsewhere. Adaptation is both economically important and contributes to reducing mortality attributable to temperature extremes.

xvii. The physical microclimatic parameters that dominate a subject's thermal perceptions need to be explained in terms of the native weather conditions. Individual variances should be considered as certain control measures and technological fixes may not be applicable. Climate adaptation strategies should be ethnically inclusive. Kitchen ergonomics creates standards for the average user, and not for an individual user. The closer kitchen ergonomics gets to an ideal state, the more it should be concerned with the people who work in the kitchen.

11.7.2 Noise

i. An investigation to control the level of noise in different kitchens and the noise emission levels from different equipment and to measure workers’ reactions in terms of their satisfaction levels. Some noises disturbed the workers more than other noises in the kitchen as noise levels varied widely in different areas.

ii. The development of a model based on Percentage Mean Vote/ Predicted Percentage Dissatisfied with high prediction accuracy for acoustics needs to be established for acoustic comfort and guidelines developed for maintaining lower noise levels in different kitchen areas to improve hearing ability among workers in noisy kitchens.

iii. The perception of loud noise as nuisance varies among ethnic cultures. There is a need to examine the impact of demographic variables on workers’ perceptions of kitchen noise on dining experience. The noise from kitchens interferes with diner experience and communication that could influence business. The impact of kitchen sound leak on a diverse sample of customers and restaurants in different geographical locations needs investigation.

iv. Comparative studies could assist with identifying confounding factors for acoustic comfort in and around kitchens. The sound leak from nearby rooms, shops and buildings could impact on kitchen noise and dining noise levels.

v. The influence of structural materials and finishes in kitchen spaces and their role on noise levels and worker exposure is a less investigated domain. Such investigation will inform prudent combinations of materials and finishes and design for specific types of kitchen based on cuisine, kitchen load and worker density.

vi. The investigation of focused psycho-socio-acoustic studies aims to establish the precise correlations between the choice of acoustic indices, noise annoyance, the effect of background noise and noise emergence. Such investigations will assist in better acoustic design to benefit kitchen workers and customers.

11.7.3 Ventilation and humidity

i. The physical principles of cooking are influenced by the manner in which the kitchen staff uses the appliances and the ventilation in kitchens when impacted by cooking options; association of these two parameters in future studies will disclose the confounding factors affecting ventilation and humidity that impact on indoor environmental quality.

ii. Further studies to embark on the association of the discharge velocity from perforated perimeter supply and thermal comfort in commercial kitchens. The modifications in mechanical devices specifically made considering age, worker height, gender and race will alleviate thermal discomfort.

iii. Analyse the effect of the association of CO_2 levels higher than 1 000 parts per million and decrement in decision-making performance of kitchen workers need further research. This would lead to a better understanding of the reactions to heat stress among kitchen workers.

iv. There is a need for enhanced understanding of cooking emissions around the world, particularly traditional food from Africa in commercial kitchens and CO_2 emissions depending on fuels used and cooking methods. The current study included a diverse cuisine; however, African cuisine was omitted.

v. It is a necessity to examine the composition of cooking fumes in commercial kitchens of South Africa, particularly African cuisine. A lack of published studies on emission from African cuisine hinders improvement in indoor air quality in African kitchens.

vi. Research on creating mathematical models with the volume of airflow displaced by extractors, air velocity from diffusers, cooling air temperatures, temperatures near stoves at various heights and discomfort levels in kitchens. The resulting equations will help to appreciate the dynamics of a commercial kitchen. This appreciation is vital for better ventilation and humidity that has an enormous impact on indoor environmental quality.

vii. Data on humidity and airflow in passageways to the kitchen or corridors leading from dining rooms to the kitchen to be gathered to understand the relationship between ventilation and workspace. Assess the relationship between multiple components of workspace ratio that has a large impact on airflow and thermal comfort, ventilation adequacy and kitchen load in commercial kitchens contributing to the uniqueness of indoor environmental quality of a commercial kitchen.

11.7.4 Lighting

i. Against a background of varied employee vision and the detail of some kitchen activities, investigations to elicit better lighting for specific tasks will reduce visual discomfort. Along with fixture selection, such study will serve to reduce strain and weakened kitchen worker eye-function.

ii. The relationship between the use of energy-efficient light sources with minimum heat emissions and measures to eliminate glare and flicker for visual comfort needs to be established for better visual and thermal comfort.

iii. As each worker has a unique personality, it is important to consider individual non-visual light effects when designing new kitchens and new standards for electrical light and daylight. The non-visual effects of lighting influence circadian rhythms, alertness, cognitive functions and worker well-being. Evaluate inter-individual aspects of the light requirement that varies with age, when integrated with designing light at workspaces highlights individual visual comfort. This will assist to prevent eyestrain, fatigue and unnecessary bending for better vision.

11.8 Improvements in research design

11.8.1 Methodological challenges and reflection

The evaluation of indoor environmental quality on comfort relies on occupant surveys, which typically focuses on long-term, one-time evaluations of occupant comfort generally over a week or a short-term measurement. Given the limited period of access and data logging and mobile measurement carts were not permitted due to logistics involved such as the bulkiness of carts, higher occupant traffic and space issues, the study conducted spot measurements. The exploration of all physical parameters recorded for 15–20 minutes, over time (30-s time-interval) using handheld instruments.

The declined gatekeeper permissions in some kitchens cannot assure indoor environmental quality across all types of food service operations were included. However, the sample included kitchens offering a wide-ranging menu. Greater participation would have enhanced the exploratory results. Unavoidably, the interviews with sampled workers could not be conducted in the same circumstances. The location, time and conditions in each kitchen during the interviews were not uniform due to the shift system and variation in the number of available staff. Consistency will have deepened the findings.

Several of the envisaged measurements were not feasible over the rush during peak periods, characterised by a high level of kitchen activity and worker movement. Among these missed measures, were the worker body temperature, volume of airflow in the extractors and the size of ducts. These snags hampered the depth of the findings especially in respect of the ventilation of kitchens. Another methodological issue faced was due to the fast-paced activities in some kitchens due to busy period. The correlation between thermal comfort and sampled workers' opinions were not correlated because the indices required for thermal comfort equation could not be collected due to the activities involved in the production process. Such correlation will have indicated the comfort index of kitchen workers. Future studies should focus on long-term evaluations of occupant comfort in kitchens using data loggers for all five parameters in kitchens.

The data collection technique for measured variables has limited the robust analysis of the results. In particular, the study was completed with spot measurements at Level 1 protocol. As data logging was not permitted, and spot measurement taken, continuous readings that would reflect fluctuations in readings timeously were not taken. In Level 2, information from Level 1 needs to be supplemented by data logger measurement and compared to published references as in ASHRAE Standard 62.1 and Environmental Protection Agency (EPA 2017: 3) standard which is valid for offices and schools. If available, the benchmark for Level 2 would be comparable to a national database.

11.9 Contribution to research

In addition to functional suggestions, the current study also offers additions to current literature. In particular, and it advances contemporary identification of how commercial kitchens can be effectively managed for fundamental improvements in the indoor environment quality for the well-being of kitchen workers. Hence, the wide-ranging analysis of this study added to existing research by identifying and reinforcing a number of personal factors that affect kitchen worker experience of environmental parameters. Albeit exploratory, this is a pioneering investigative study for two reasons: firstly for its Durban location and, secondly, for the investigation of effects of all five indoor environmental parameters. However, no significant combined relationships between the parameters could be confirmed. The study has confirmed that further to building design characteristics, kitchen worker adaptation to heat, ventilation, noise and lighting is influenced by individual genotype and phenotype of a kitchen worker such as age, height, race, work experience and correct body weight.

Novel equations derived in the study accounted for the role of multiple variables affecting different dimensions of the different environmental parameters in a commercial kitchen. Although some researchers collected primary and secondary factors in earlier studies, the influence of severable weighty variables on indoor environmental quality is discussed partly and or not reported. These equations reported for the first time indicate that even subtle changes in certain minor elements and features in kitchens can affect the experience of kitchen workers.

While the results of the study nonetheless affirm prior empirical work, it expands existing notions in the prediction of heat near stoves by accounting for the combined effects of the explanatory variables namely, type of kitchen, job position, and years of employment and worker shift in a multiple linear regression model. Increased space in kitchens tends to reduce worker heat experience. The study revealed a newer model to understand heat near stoves, not observed in previous accounts.

The best fitting model for predicting heat near the stove is a linear combination of symptoms of face is red among kitchen workers and discomfort index (due to heat from stove or oven). Other stepwise regression model for predicting heat near the stove is revealed by several mathematical models. Among these is a linear combination of races-South African Indian, South African (African), area of the kitchen, output in the number of meals per day and other cuisines. The study unveiled several factors affecting the heat experienced by kitchen workers, specifically for those near stoves, grillers and bakers. These include kitchen height, symptoms face-red, sweating, discomfort index, space ratio and state of the uniform.

The current knowledge has been extended in respect of perception of thermal comfort for kitchen workers. The study had afffirmed that thermal comfort can be determined by individual factors such as age, gender, body mass index, fitness, acclimatisation, ethnicity, type and scope of kitchen activities, cuisine, style of service, volume of meals prepared, number of plated meals and peak activity time. In addition, the study elicited that the ability of kitchen worker to cope with thermal strain can occur from the combined influence of age, gender, race, body weight, fitness and work experience.

The research underscored a strange phenomenon of assumption and prediction of the body mass index of a kitchen worker. Female workers tend to assume positively about their fitness which has a positive psychological effect on heat adaptation.

As expected, the study results indicated that the combined effect of temperature and humidity - wet bulb globe temperature was high in different kitchen zones. Besides higher readings of wet bulb globe temperature, excess hair on head or wearing of wigs in kitchens increase worker discomfort from heat.

The study affirms increase in discomfort index caused by heat from stove or oven along with the effect of poor airflow. The research finds the ideal balance of natural and mechanical ventilation remain elusive and is a factor certainly not mentioned in prior studies on kitchen indoor environmental quality. An effective, yet practical solution to staff complaints about difficulty in breathing and hot drafts can be alleviated by higher ventilation rates by simply opening kitchen back doors. This can improve the oxygen levels to 22 %.

The study also develops the present concept of predicting humidity near stoves by several factors. The understanding of humidity is further extended by the recognition of ethnicity, mechanical devices for ventilation and, physiological and psychological symptoms of heat stress.

The escalation of the lighting measures to a multivariate regression model revealed the association of human well-being in the workplace in respect of headaches could be prevented by an increase in natural light and with clean lights and fixtures. The study showed that effort for clean lights, adequate lighting and good maintenance of lighting provide visual comfort in commercial kitchens. The seemingly obvious, but without mentioned in earlier studies is the significant correlation between light, and clean and adequate lighting in cooking areas. With the addition of task light and infrared light, the incidence of adequate lighting in kitchens is likely to result in fewer staff complaints about contrast in the kitchen.

Further to the significant and well published benefit of sunlight in work areas, satisfaction with visual comfort arise from adequate and clean lighting, and lighting equipment being in good repair. By contrast, visual discomfort derives from inoperable windows, unequal distribution of natural light, glare and contrast. Prior to the study, no published work was available regarding lighting in kitchens or the effect of lighting on kitchen workers. Several aspects of kitchen lighting and their effects on workers were illustrated in this study.

Correspondingly, as predicted by previous studies, workers were unable to communicate because of noise from gas stoves and grinders. A new element highlighted in this research show that the reaction to stove noise affect by gender, age and race of the worker. The study has also established that noise and heat produced from dishwashing machines are sources of discomfort.

The current study elicited new information on the adequacy of kitchen workspace and the need for workspace ratio measures in South Africa. The role of worker density in commercial kitchens that has not featured in prior work emerged as affecting ventilation and hence thermal comfort.

One of the significant shortcomings in the current literature is the scarcity of readings/publications relevant to kitchen environmental ergonomic parameters. The study embraced the opportunity to identify new gaps in the prior literature and to present the need for further development in this area of study to contribute to the body of knowledge. The studies on worker comfort are very limited and hence this is a pivotal study.

The investigation results emphasize an employee well-being approach for enhancing worker comfort levels in terms of heat, ventilation, humidity, airflow, noise and lighting that may contribute to sustained worker health and retention.

The study provides insights to advance understanding of cause and effect relationship of five study parameters with human responses in a commercial kitchen. Of these five, personal factors analysis revealed that in comparison, thermal comfort is most influenced in the kitchen than the other four other parameters. In this regard, age, gender and BMI emerged as significant personal factors influencing thermal comfort.

The recommendations offer kitchen and restaurant management advance a better work environment to achieve the goals of a catering business. Worker satisfaction is a necessary ingredient for improved survival, performance and productivity.

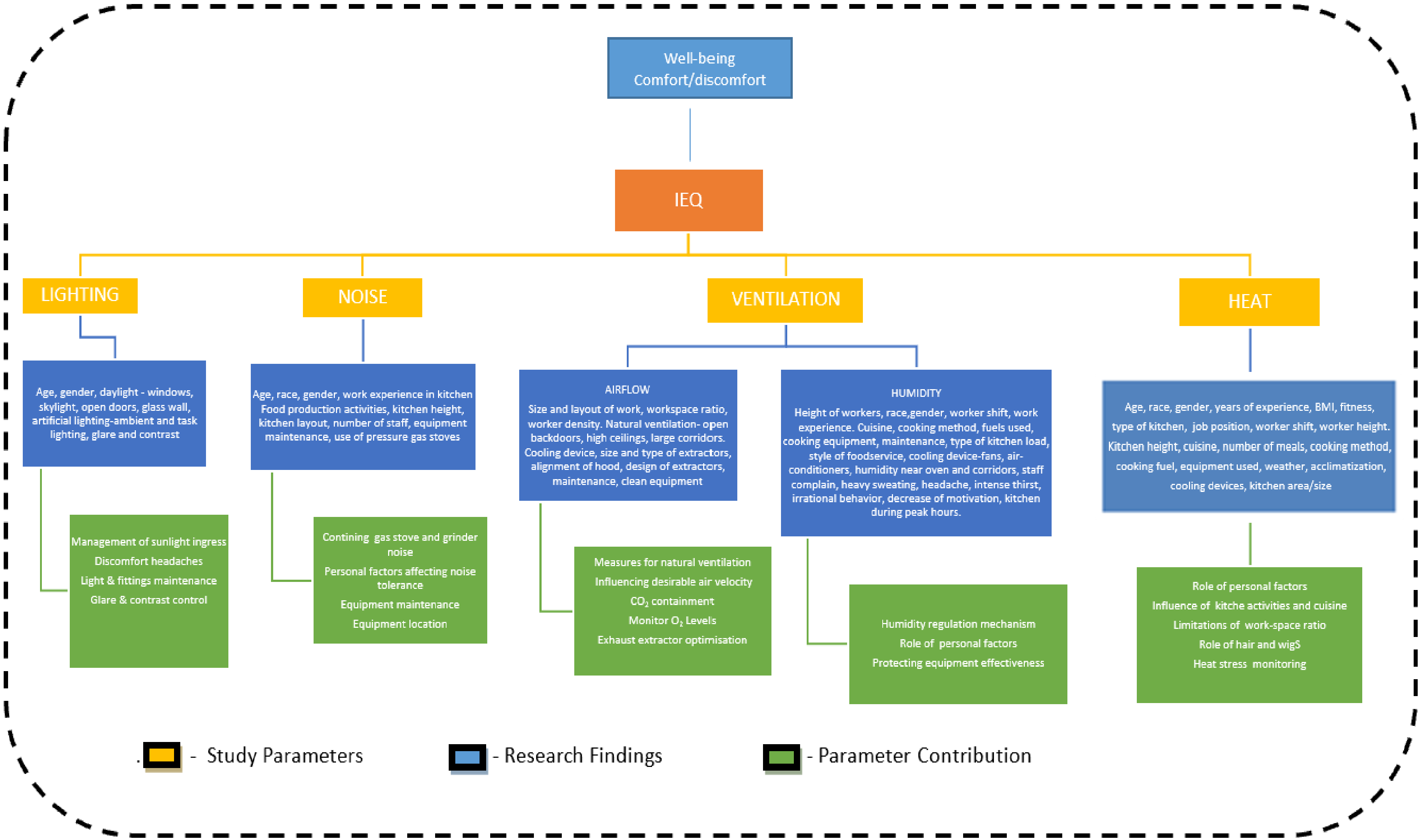


Figure 11.1 Kitchen IEQ framework by researcher

The framework advanced in Yang and Moon (2019: 630) in section 1.5 on optimal IEQ was performed in controlled chambers. The empirical work in the present study shed light on the actual working kitchen environment, specifically in food preparation and production areas. Consequently, a new framework (Figure 11.1) emerged, that highpoints the significance of kitchen environment, the physical layout, fittings and fixtures.

In the current research, five elements indicated misalignment from optimal conditions. The initial working framework in Figure 1.2 consists of three comfort attributes under steady-state thermal conditions.

The impact of acoustics on indoor environmental comfort was the greatest among the three factors-thermal, light and acoustics tested in this study. On the other hand, the current study reports that heat has maximum influence on the indoor environmental comfort of Durban kitchens with food service workers changing behaviours to cope with heat stress.

In the new framework, personal factors, kitchen activities and cuisine, workspace ratio, hair and wigs, and heat stress monitoring impacts temperature in these kitchens whereas the old framework finds that thermal comfort is affected by thermal factors, acoustics and illumination factors. Correspondingly, factors such as air velocity, CO_2 containment, exhaust extractor optimisation, and humidity regulation, personal factors and equipment effectiveness control ventilation in kitchens.

Ventilation was lacking in the original framework. Ventilation is essential in providing safe and efficient working conditions for food service workers while also protecting their health. Kitchen ventilation is necessary for controlling air contaminants, humidity and temperature generated by cooking processes.

The new framework highlights the physiological and psychological influences of five parameters. The five parameters accounts for human demographics such as age, gender and race; hairstyles, uniforms and skin colour are shown to also affect thermal comfort and hence human well-being in kitchen. The relevance of the initial framework is restricted to age, gender and BMI, with age band from 19 years to 25 years, whereas the age range of current study varied from 18 years to 61 years. The outcomes of the initial framework ignores the influence of race, hairstyles, clothes/uniform, skin colour that could influence comfort from heat.

The variables were controlled and reactions noted in the initial framework whereas the variation in parameters occurred due to food production process in a natural setting. The temperatures increased by 5 °C (20, 25, and 30 °C) whereas the temperature (preparation areas) ranged from

28.97°C to 33.70 °C, and 27.56 °C to 30.85 °C in an Oriental cuisine kitchen. These temperature ranges were effected by menu, cuisine, food production system, volume of cooking, staff space ratio, layout, natural ventilation and mechanical ventilation influenced heat experienced.

Regarding the light parameter, the initial framework found 500 lux to be optimal. However, the current framework reports multiple factors influence light comfort namely, management of sunlight ingress, discomfort headaches, fixtures and fittings maintenance, contrast and glare control.

Similarly, the initial framework is derived from a reported optimal of 35dBA. Conversely, the outcomes in the new framework is derived from the noise range of 59-96 dBA (preparation area) to control noise from cooking process, personal factors, equipment maintenance and location.

Table 11.1 Summary of influences on Initial and Revised Framework (by researcher)

	Comparison	**Original framework** Yang and Moon's study (2019)	**Newly developed framework** Researcher's study (2021)
1.	Environment	Controlled chambers	Food production kitchens
2.	Parameters	Three comfort attributes under steady- state thermal conditions.	Five elements indicated misalignment from optimal conditions.
			Physiological and psychological influences of all five parameters.
3.	Participants	60	Kitchen workers 170 Head chefs/kitchen managers 33
4.	Demographic similarities	Age, gender and BMI.	Age, gender and BMI.
5.	Age	Young university students age varied narrowly from 19 years to 25 years	Large variation in kitchen worker's age varying from 18 to 61 years
6.	Variables	Clothing ensemble of nearly 0.75 clo as per ASHRAE Standard 55-2004.	Various types of uniform. Race, skin colour, hairstyles.
7.	Physical parameters influencing comfort	Test laboratory	Physical layout, fittings and fixtures in operational kitchens.
8.	Light	500 lux as optimal	Individual management of sunlight ingress, discomfort headaches, fixtures and fittings maintenance, contrast and glare control
9.	Noise	35dBA as optimal.	Individually planning and controlling of noise from cooking process, personal factors, equipment maintenance and location
10.	Heat	Thermal comfort affected by thermal factors, acoustic and illumination factors	Adds personal factors, kitchen activities and cuisine, workspace ratio, hair and wigs, heat stress monitoring
11.	Ventilation	Not a part of the study	Accounts for the influence of air velocity, CO_2 containment, exhaust extractor optimisation, humidity regulation, personal factors and equipment effectiveness.

11.10 Conclusion

This exploratory study will help scholars and practitioners to expand a repertoire of actions and responses, towards an optimum combination of approaches that best fit individuals. The study has demonstrated that the exploration and assessment of interpretations entail trans-disciplinary approach, including methodical resolutions, a blend of provincially suitable expertise incorporated with human privileges and eco-friendly sustainability.

The overall human comfort experience in kitchens is catalysed by several environmental factors simultaneously including heat, humidity, ventilation, acoustics and light. However, procedural standards and design strategies typically focus on a single environmental factor separately. This exploratory study provides an orientation for additional explorations with better perception, modelling, or extrapolation among numerous workplace surroundings and human well-being in kitchens. It continues to be necessary for such research to embrace an all-inclusive outlook, as the link between indoor environmental parameters are likely to influence behavioural adaptation.

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APPENDICES

Appendix 1 High risk occupations and behaviour modification to overcome heat stress

Source	**Location of study**	**Type of workplace /Occupation**	**Heat generating factors - Temperature at workplace, body heat & PPE**	**Danger to worker - Effect On Worker Physiology/ work**	**Adaptation Adopted**	**Adaptation Recommended**
Hunt *et al.* 2014	USA	Surface Mine	Core body temperature 37.46°C Exertional heat, air temperature, PPE	Dehydration & heat illness- heat exhaustion & heat stroke	Consumption of water, tea, coffee, soft drinks & sports drinks	Preventative hydration
Miller and Bates 2007	Western Australia	outdoor workers at Surface mines	WBGT≥ 30 °C	Hypohydration reduces productivity and increases risk of accidents & injuries	Habitual fluid intake	Monitor hydration status. Education on Adequate hydration -1L/hr of cool water or industrial rehydration fluid, consume food at meal breaks to replace electrolytes & maintain energy, limit intake of caffeine, provide shade or increase ventilation
Kolkowsky *et al.* 2006	Germany	Coal mine	Core body temperature 37.7°C. Exertional heat, air temperature, humidity, PPE- 14 kg	Dehydration due to high sweat rates	Increased sweat rates Acclimatization permitted for beginners <21&51 yrs need medical approval	Preventative hydration
Donoghue *et al.* 2000	Queensland, Australia	Metalliferous mine	WBGT 29°C Exertional heat, humidity, PPE	Dehydration, Muscle cramps, Heat exhaustion- headache, nausea, weakness, dizziness, clammy skin, rapid heart rate, irritability		Increased fluid intake, improve ventilation & air cooling at all sites
Donoghue 2004	USA	Mine	Exertional heat, air temperature, humidity, PPE	Heat illness greater in dayshifts in summer		Self pacing, training, medical clinic on site
Bates *et al.* 2001	Australia	Mine	Outside temperature 40°C. Exertional heat, PPE	Heat strain & dehydration		Monitor heat stress index
Shearer 1990	South Africa	Gold mine	Exertional heat, air temperature,radiant heat from rocks- 55°C relative humidity-92% PPE	Muscle cramps, Dehydration & salt depletion, Heat exhaustion	Water not palatable all the time- Voluntary hydration, education	Heat stroke till 1970 A/C reduces temp from 55°C to 28°C. Citrus flavoured tablet/powder, Training program, improve ventilation & cooling systems in all areas
Mclellan and Selkirk 2006	Toronto, Canada	Fire fighters	Body temperature 39°C. air temperature, PPE & SCBA load (self containing breathing apparatus)	Heat stress	Passive cooling	Fluid replacement & active cooling. Rest & self pacing. Shorts and T-shirts under bunker pants reduce heat strain

Kales *et al.* 2003	Cambridge, USA	Fire fighters	Air temperature, PPE	Heat stroke & Heat exhaustion, Coronary heart disease(CHD) lead to death		Activities of fire suppression, training & alarm response had higher rates of CHD
Biggs *et al.* 2010	South Africa	Forestry workers	Exertional heat-logging wood, air temperature, PPE	Dehydration & Hyperhydration-hyponatremia	Water provision - Inadequate, inconvinient, inadequate toilet facilities	Rehydration strategies, Education
Maeda *et al.* 2006	Japan	Forestry workers	Exertional heat-logging wood, air temperature, PPE	Heat stroke in summer. Higher frequency among younger persons due to lower adaptation. But frequent among elderly due to a decline in thermoregulation capabilities		Isotonic drinks for efficient source of water & electolytes. Temporary tents for rest, electric fans for ventilation and automated machine cool drinks
Bates *et al.* 2001	New Zealand	Forestry workers	WBGT 12.4°C to 21.7°C. Exertional heat-logging wood, PPE	High metabolic heat, Hypohydrated or dehydrated		Maintain hydration status. Increase fluid intake without caffeine and sugar. Slices of lemon to flavour water, cool in insulated containers, Camel-bak fluid carrier
Stoecklin-Marois *et al.* 2013	California, USA	Farm workers	Weather conditions-Air temperature, radiant heat, humidity, PPE	Heat related illness & death		Potable water, shade, toilets & rest. Training on heat related illness Gender specific approaches
Cortez 2009	Nicaragua	Sugarcane farm workers	WBGT 28°C to 30.4°C.		Rehydration solution, cool water, 1L water before work & 500ml every 30 min	New rehydration measures improved productivity- 5.8 to 8 tons of sugarcane cut per worker per day
Mirabelli *et al.* 2010	North Carolina, USA	Agricultural workers	Climate in summer-Air temperature, PPE	Heat illness - fainting, sudden muscle cramps. Heat related fatalities		Change in work hours & activities, drinking more water, rest in shade, air conditioned places. Reduce workers environmental heat exposure.
Knowlton *et al.* 2009	California, USA	Agricultural workers	Air temperature, PPE	Heat wave causes hospitalisation & death		Potable water, shade, toilets & rest.
Mirabelli and Richardson 2005	North Carolina, USA	Agricultural workers	Summer temperature 90°F (°C) or higher-climate & exertional heat	Heat stress. Heat related death among Latinos & African Americans, especially young men		Medical attention
Rowlinson *et al.* 2014	China	Construction workers	Human factors-metabolic heat & clothing. Climate	Heat induced illness & fatigue		Control environmental heat stress exposure, control of continuous work time-CWT with mandatory work-rest regimen, self pacing

Marioka *et al.* 2006	Japan	Construction workers	WBGT 23°C to 34°C. Exertional heat, PPE	Increased blood pressure	Break during work, tents & electric fans, cool drinking water	Restrict work hrs, monitor water intake, Health education & Training
Bates and Schneider 2008	UAE	Construction workers - Expatriates	WBGT 28.6°C Dry bulb 42.5°C Globe temp- (Radiant heat) 52.1°C at noon in summer	Fatigue		Adequate fluid intake (2L of water every 2-3hrs). self pacing
Inaba and Mirbod 2007	Japan	Construction workers & traffic controllers	WBGT exceeding exposure limit values. WBGT 28.1°C -32.0°C (9:00am to 1:00pm), PPE & Uniform	Heat related subjective symptoms-fatigue, impatience, headache, dizziness		Traffic workers-Use of sunglasses, covering face and neck, changing clothes frequently. Improve acclimatization, work & rest cycle, increase fluid intake, altering clothes frequently, Access to A/C places, sunscreen
O'Connor 2010	USA	Military	Exertional heat, Air temperature, PPE	Exertional heat stroke(EHS) Acclimatization cannot cope with over- exertion		Improved biomarker in testing recovery. Induce Acquired Thermal Tolerance(ATT)
Carter *et al.* 2008	USA	Armed forces	Ambient temp ≥40.0°C. Exertional heat, PPE	Heat illness & heat injury. Fluid & electrolyte imbalances- hyponatremia. Heat exhaustion & heat stroke higher in infantry soldiers, Caucasians from Northern US & Females		Vigilant Medical Personnel. Strategy to identify high risk personnel
Dang *et al.* 2014	Texas, USA	Aluminium smelter	Ambient temp 78.0°F- potroom	**Heat Strain**- Unacclimatized person Core body temp>100.4°F (°C)- **off work for 4 days or more in 2 weeks.** Acclimatized>101.3 °F (°C) Blood & urine samples significant		Adequate hydration & Acclimatization
Parameswarappa & Narayana 2014	Karnataka, India	Steel workers	WBGT °C 28-34- hot rolling ares, casting platforms, furnaces. Local temp 43°C, PPE. 50% had discomfort in PPE. Work not suitable for ≥50 yrs old men	High core body temp, more than permissible limit. Heat strain		Reduced work period, intermittent rest. Cool thermals. A/C rooms
Bates *et al.* 2010	Middle East	Manual workers	Construction site workers less hydrated than industrial workers	Inadequate hydration status		Pre-work fluid intake, programs to inprove hydration, monitor heat in environment
Chen *et al.* 2010	Hongkong	Steel workers	WBGT °C 25.4 to 28.7 & WBGT 30 °C to 39 °C- electric arc melting & casting	Fatigue & thirst- heat strain & **poor reflexes**		Self pacing, air cooling. Increase fluid intake & preventative drinking before work. Provide drinking fluids at work sites

Balakrishnan *et al.* 2010	South India	All industries	WBGT 34 °C Core body temp 39 °C (reduces by 4-5 min per 1°C increase of WBGT)	Tolerance time for heavy work is < I hr. Heat stress. Reduction in physical work ability due to heat exposure		Monitor discomfort, disability to work, work performance
Ayyappan *et al.* 2009	Chennai, India	Automotive industry		28% workers heat stress		Assess efficacy of heat interventions
Brake & Bates 2003	Australia	Industrial workers	Environment- WBGT 30.9°C	Dehydration. Hypohydration before work shift	Awareness on hydration and consume lunch and fluids in meal breaks	Urinary specific gravity limits before shift starts=1.022. Workers exceeding this value were not allowed into workplace. Improve workforce awareness
Kjellstrom *et al.* 2013	Australia, India, Nepal, Ghana, Thailand, Vietnam, Costa Rica	All workplaces Pregnant women & children included	Dry bulb 37 °C- 40 °C	Heat stress - Decreased productivity		Public message & information on heat exposure & risks
Simone and Olesen 2013	USA- different cities in summer & winter	kitchen workers	Dry bulb up to 41.2 °C (°F) Heat from cookers, stoves, grillers, humidity from water usage	Uncomfortable environment		Opening windows
Li *et al.* 2012	China	kitchen workers	Dry bulb varied from 18.5 °C to 54.0 °C in different kitchens. Heat from cookers, stoves, grillers, humidity from water usage	Thermal dissatisfaction decreased productivity	O	Improved ventilation system in naturally ventilated kitchen
Matsuzuki *et al.* 2011	Japan	kitchen workers	WBGT 27.5°C Dry bulb 22.8°C. Heat from cookers, stoves, grillers, humidity from water usage	Heat stress- fatigue & dehydrationkitchen workers take break from work	O	Recommendation: Rest & Pacing
Haruyama *et al.* 2010	Japan	kitchen workers	MRT up to 36.4°C	Thermal strain	O	Dry floors reduce humidity in kitchen
Eagles & Stedmon 2004	London, UK	kitchen workers	Dry bulb temp 22.8 °C Heat from cookers, stoves, grillers, humidity from water usage	O	O	Open kitchen windows, install more extractor fans & ventilation hoods
Totsky (2006)	Michigan	Chefs, Kitchen workers	WBGT 25.5°C to 35.7°C Outside temperature 35.5°C	Heat exhaustion, heat fatigue	Circulating fans, drink water, acclimated workers	Preplacement screening of susceptible workers, monitor cool drinking water-1 cup every 20 min, use proper clothing, rest in cool place, provide shielding from radiant heat, adequate ventilation, a/c in kitchen, training on symptoms of heat stress, pacing.

Logeswari & Mrunalini 2017	Telengana, India	Cooks, Kitchen workers	WBGT 84.2°F (27.8) Mean ear temperature 39 °C, higher than WHO permissible limit	Heat stress		Training on heat stress, improve ventilation, loose fitting clothing, adequate drinking water-5L/day, breaks between work

O = no data reported

Appendix 2 Summary of cooking fumes affecting IAQ in kitchens

Author and Country	**Source**	**Pollutants**	**Health**
1. Cooking appliances and cooking process			
Ho *et al*. (2006: 1091) Hong Kong	Cooking fumes	Carbonyl emission-formaldedyde	
Katragadda *et al.* (2010: 59)	carbonyl emission-	Acrolein	
Srivastava *et al.* (2010: 1343)	carbonyl emission-	Acrolein	
Wong *et al*. (2011: 746), China	Gas-fuelled kitchens	NO, NO2, CO, CO_2, CH4 and TVOC	Poor lung function
Jiang *et al.* (2012)	Cooking area	CO_2	Impact on the staff's physical health
Singh *et al*. (2016: 205) India	Cooking appliances, process of cooking	CO, TVOC and PAH	Decline in lung functions
2. Cooking fuels			
Ezzati and Kammen (2002: 1057)	Solid fuels- biomass and coal	PM, SO_2, NO_2, CO, benzo[*a*]pyrene	ARI (acute respiratory infections), COPD (chronic obstructive pulmonary disease), cancer
Lissowska *et al.* (2005: 327) Czech Republic, Hungary, Poland, Romania, Russia, Slovakia and the United Kingdom.	Solid fuels	Indoor pollution	Lung cancer
Barnes *et al*. (2006: 7) Eastern Cape, South Africa	Wood and cow dung		ARI
Siddiqui *et al*. (2008: 544) Pakistan	Wood fuel	CO and $PM_{2.5}$.	Hazardous concentrations
See and Balasubramaniam (2008: 8852)	Gas cooking	$PM_{2.5}$	
Wong *et al*. (2011: 746)	Gas kitchens	Nitric oxide (NO), NO_2, CO, CO_2, methane (CH4) and TVOC	Poor lung function and respiratory symptoms
Seltenrich (2014: A155).	Electric coil burners in stoves, ovens and toaster Gas burners	UFP NO_2	
Zhao *et al*. (2014: 560) China	Increases in temperature, wine, marinade	CO_2 and TVOC	
Sharma and Jain (2019: 240) India	wood, crop residue, dung cake or coal		Affects health of cook
3.Cooking oil			
Lin and Liou (2000: 817) Taiwan	Preheating oil stir-fry, pan frying	Benzo[a]pyrene, dibenz[a,h]anthracene, benzene and formaldehyde	Carcinogens
Metayer *et al*. (2002: 111) China	Cooking oil fumes-rapeseed oil	Mutagenic substances	Risk of lung cancer
Fullana *et al*. (2004: 5207)	deep-frying of oil	Low molecular weight aldehydes	
Chatzilazarou *et al*. (2006: 34)	Oil deterioration		
Alomirah *et al*. (2010: 869), Kuwait	Olive oil and cooking oil	Benzo[*a*]pyrene (BaP)	Carcinogen
Srivastava *et al.* (2010: 1343)	Repeated heating of vegetable oils	PAH	Changes in the liver.
Svendahl *et al*. (2012: 230) Finland	Cooking fumes	Aldehydes, alkanoic acids, polycyclic aromatic hydrocarbons and heterocyclic compounds	Deleterious health effects
Lee and Gany (2013: 649) Singapore	COF Chinese, Malay stalls	Condensate of the fume from cooking oils PAH and PM	Genotoxic, mutagenic, lung cancer.
Sebastian *et al.* (2014: 420) Toronto	Used oil	PV, TPC, FFA	High levels of oxidation
4.Cuisine			
Seow *et al.* (2000: 2) China	Frying of meat-beef, pork	Heterocyclic amines-carcinogen	Risk of lung cancers
Abdullahi *et al.* (2013: 261)	Charbroiling-fatty meat	Higher PM2.5	
Wang *et al.* (2015)	Barbecue- cooking fume	High mass fractions of organic acids	
5.Cooking methods			
Lee *et al.* (2001: 181)	Barbecue	CO, PM_{10} and $PM_{2.5}$	
See and Balasubramaniam (2008: 8852)	Deep frying	Nanoparticles, PM	
Lee and Gany (2013: 649) Finland, Norway	Frying and grilling	High levels of fat aerosols, acrolein and formaldehyde	
Peng *et al.* (2017)	COFs	Deep frying	

Appendix 3 KMO and Bartlett's Test

	Kaiser-Meyer-Olkin Measure of Sampling Adequacy.	Bartlett's Test of Sphericity		
		Approx. Chi-Square	df	Sig.
Facility design and layout- Lighting	0.500	26.986	9	0.000
Presence of Natural light	0.519	31.774	15	0.007
Dishwashing machine - noise + heat	0.500	2.220	1	0.136

Appendix 3a Questionnaire for food service managers / head chefs

Dear

My name is Sasi Gangiah. I am a registered post graduate student of the Durban University of Technology undertaking doctoral research in Management Sciences. For my doctoral dissertation, I am interested in conducting advanced study on environmental ergonomics in restaurant kitchens. I therefore invite your valued participate in a questionnaire around the topic.

Whilst your participation in this study is completely voluntary, it is very valuable. Your inputs and your comments will go a long way in providing valuable information on working conditions in kitchens. It will take approximately 20 minutes to complete the questionnaire. Your survey responses will be strictly confidential and data from this research will be reported only in the aggregate. Your information will be coded and will remain confidential.

Please ask any questions that you have about participating in this project at any time. I want you to have the information you need to make a decision that is best for you. You may contact me at (031) 3735615 / 0843324331 or by email: sasig@dut.ac.za

While there is no obligation, any further assistance that can be granted to me from your knowledge resources to complete my study will be appreciated.

Yours sincerely,

Mrs. Sasi Gangiah,

Lecturer

Department of Hospitality and Tourism

Durban University of Technology

QUESTIONNAIRE FOR FOOD SERVICE MANAGERS / HEAD CHEFS

Instruction:

1. Please give complete details relating to all aspects.
2. If information requested for is not applicable, please mention n/a.
3. Please tick wherever appropriate. Additional information may be filled in the spaces provided.

Demographics

1. Gender____________________
2. Designation__________________________
3. Age___________________
4. No. of staff on shift --
5. Which of the following best describes the ethnicity of the staff:

Ethnic background	S.A. White	S.A. Indian	S.A.-Mixed (Coloured)	S.A. African	S.A Other mixed race	European White	Foreigner	Other Africans
No. of Staff								
Other, please specify:								

6. What is the area of the kitchen?

20 ≤100sqm	101≤200sqm	≥200 sqm	≥300 sqm

7. What is the output in number of meals per day?

500≤750	250≤500	100≤250	10≤100

1

8. What is the average output in number of plated meals per shift?

≤250	≤150	≤100	≤50

9. How many workers are in the kitchen?

≤25	≤20	≤10	≤15

10. What is the seating capacity of the restaurant?

≤40	41≤80	80≤150	150≥200	≥250

11. What are the different types of foodservice offered from your kitchen?

No. of meals	Plated meals	Room service	Buffet no. of portions	Take away
0-20				
21-40				
41-60				
61-80				
81-100				
101-120				
121-140				

12. What is the dominant Cuisine?

Continental	Contem-porary	Indian	Oriental	Italian	Portuguese	Fusion

Other, please specify---

13. What restaurant service style does the kitchen serve?

Family restaurant	Casual	Pub	Coffee shop	Cafeteria style	Quick service	Fine dining

Other (please specify) ---

2

14. What is the average numbers of diners at meal times?

Covers	BREAKFAST	LUNCH	DINNER
0-20			
21-40			
41-60			
61-80			
81-100			
101-120			
121-140			
141-160			
161-200			
201-250			

15. How often do you filter fryer/frying pan oil?

Daily	alternate days	thrice weekly	twice weekly	fortnightly	monthly	Other(please specify below)

----

16. How often do you change oil in the fryer and/or frying pan?

Daily	alternate days	twice a week	Once a week	Once in 15 days	Once a month

17. How often is the electrical and mechanical equipment serviced?

----

18. What is the waiting period to repair/replace any malfunctioning equipment?

24 hours	one week	fortni ght	one month	3 months	one year

Other (please specify) ---

3

19. Please state the number of cooling devices in the kitchen

Type of cooling device	Air- conditioner	Domestic fans	Industrial fans
No. of cooling device			

Other (please specify)--

20. Has staff shown any of the following symptoms that you attribute to heat?

Tiredness	Increase in blood pressure	decrease in blood pressure	headache	muscle cramps
feeling and being sick	heavy sweating	intense thirst	a fast pulse	n/a

Other (please specify) --

21. Please tick the appropriate boxes for symptoms shown by staff due to excessive heat

Personality	confusion	irrational behaviour	any other	n/a
Behavioural	irritability	use foul language	walk away	n/a
Mental fatigue	lose concentration	anger	foul language	n/a

22. Which of the following on average, best describes the kitchen during peak hours?

Very hot	hot	warm	Slightly warm	Slightly cool	cool

23. How do the staff cope with the heat?

Drink cold liquid	step outside	take short break	sit under a fan

Other, please specify---

24. Please indicate your opinion on the highest level of influence of the following on coping with kitchen heat

Age	≤20 years	≤30 years	≤40 years	≤50years	Over 50years	n/a
Work experience	Strongly agree	agree	Not sure	disagree	Strongly disagree	n/a

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Correct Body Weight	Strongly agree	agree	Not sure	disagree	Strongly disagree	n/a
Gender- male cope better than female	Strongly agree	agree	Not sure	disagree	Strongly disagree	n/a
Race	African	India n	Coloured	Caucasian -White	Other (please state)	n/a
Fitness	Strongly agree	agree	Not sure	Disagree	Strongly disagree	n/a

25. Indicate the number of staff wearing the following head gear in the space provided

Classic chef hat	Toque	Disposable chef hat	Sailor /skull cap	Café style cap	Cap	Driver cap	Head wrap	Hair net	Mop cap

26. How long does it take to replace burnt out bulbs or flickering lights?

Immediately	1 day	2 days	3 days	1 week	I month	never

27. To what extent do you feel that staff suffer from the following due to inadequate light?

	With certainty	belief	Reservation/wariness	doubtful	n/a
Headaches					
Visual problems					
Too much bending					

28. What intervention has been taken to solve problems of lighting?

No problem with lighting	Lower the height of light	change globes	clean globes and fixtures	provide extra lighting

Correct Body Weight	Strongly agree	agree	Not sure	disagree	Strongly disagree	n/a
Gender- male cope better than female	Strongly agree	agree	Not sure	disagree	Strongly disagree	n/a
Race	African	India n	Coloured	Caucasian -White	Other (please state)	n/a
Fitness	Strongly agree	agree	Not sure	Disagree	Strongly disagree	n/a

25. Indicate the number of staff wearing the following head gear in the space provided

Classic chef hat	Toque	Disposable chef hat	Sailor /skull cap	Café style cap	Cap	Driver cap	Head wrap	Hair net	Mop cap

26. How long does it take to replace burnt out bulbs or flickering lights?

Immediately	1 day	2 days	3 days	1 week	I month	never

27. To what extent do you feel that staff suffer from the following due to inadequate light?

	With certainty	belief	Reservation/wariness	doubtful	n/a
Headaches					
Visual problems					
Too much bending					

28. What intervention has been taken to solve problems of lighting?

No problem with lighting	Lower the height of light	change globes	clean globes and fixtures	provide extra lighting

Please elaborate____

29. Which of the following factors affect adaptation to light amongst your staff?

age	gender	race	work experience in kitchen	work activity	physical fitness	health status

30. What has been done to reduce noise in the kitchen?

No problem with noise	switch the equipment off	lubricate the equipment	send equipment for repair	place rubber mats to absorb noise

Please elaborate---

31. Which of the following factors affect adaptation to noise amongst your staff?

Age	gender	race	work experience in kitchen	work activity	physical fitness	health status

Please elaborate ____

32. What intervention has been taken to reduce humidity in the kitchen?

No problem with humidity	clean extractor	open windows and doors	install fan

Please describe---

33. Rate the equipment according to the loudest source of noise to lowest source

Equipment	Rank from loudest (1) to lowest noise (11)
1.Ovens	
2.Grillers	
3.Gas stoves	
4.Fryers	

5.Grinders and blenders	
6.HVAC & fans	
7.Dishwasher	
8.Swivelling doors	
9.Trolleys	
10.Air conditioner	
11.Refrigeration	

34. Which of the following words best describe the humidity in your kitchen?

Low	optimal	High	excessive

35. The nature of staff complaints with regard to kitchen humidity are

No complaints	sweat not drying	uniform is wet	stickiness

36. How often is the kitchen ventilation system cleaned?

Daily	weekly	monthly	quarterly	bi-annual	yearly	when extractor breaks down

37. Which of the following factors affect adaptation to humidity amongst your staff?

Age	gender	race	work experience in kitchen	work activity	physical fitness	health status

38. Which of the words best describe the air quality in your workplace?

Stuffy	stale air	bad odours	clean

39. Which of the words best describe ventilation in your kitchen?

Poor	inadequate	satisfactory	Good

40. Please tick: have the staff undergone **formal/informal** training **or no training** to use gas appliances safely?

41. Kitchen air filters are cleaned at least

Once a week	Once a month	Once in 6 months	Once a year	Once in 2 years	Never

42. Please read the following statement and tick the appropriate boxes

		Yes	No
1.	Does the kitchen have adequate cooling sources?		
2.	Has any staff shifted from kitchen to other departments because they were unable to cope with heat?		
3.	Are the staff comfortable in their uniform?		
4.	Are the staff comfortable in their head gear/chef's hat?		

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5.	Are work areas free from shadows?		
6.	Can employees comfortably see their work without straining?		
7.	Is mobile task lighting provided?		
8.	Are there very loud impact noises heard in the kitchen?		
9.	Do people need TO RAISE voices to speak with someone one metre away?		
10.	Was a measurement program carried out for the following ? Please tick 10.1 HEAT 10.2 LIGHT 10.2 NOISE		
11.	Have you ever seen mould growth under the sink?		
12.	Have you seen mould growth on the kitchen walls/tiles?		
13.	Does sweeping and dusting in kitchen increase dust and particulate matter in the air?		
14.	Does the amount of fumes, mist and smoke vary during the day?		
15.	Do you have adequate measures to extract particulate matter during repairs, installation or construction in kitchen?		
16.	Do your staff smoke in the kitchen?		
17.	Does contaminated outdoor air leak into your kitchens through your doors/ windows?		
18.	Does the kitchen have any room temperature control? If yes, please elaborate-- --		
19.	Are there deliberate measures to prevent excessive noise? If so please elaborate-- --		

Appendix 3b Food service worker interview schedule

Hello,

My name is Sasi Gangiah. I am a registered Post Graduate student of Durban University of Technology who wishes to pursue a Doctorate Degree in Management Sciences. I wish to conduct an advanced study on Environmental Ergonomics in Restaurant Kitchens in Durban. I therefore, invite you to participate in an interview around the topic.

Your participation in this study is completely voluntary but very valuable. Your inputs and your comments will go a long way in providing valuable information on working conditions in kitchens. It will take approximately 20 minutes to complete the interview. Your survey responses will be strictly confidential and data from this research will be reported only in the aggregate. Your information will be coded and will remain confidential. If you have questions at any time about the interview or the procedures, you may contact me at (031) 3735615 / 0843324331 or by email: sasig@dut.ac.za

While there are no obligation, any assistance that can be granted to me to conduct this study will be appreciated.

Thank you,

Mrs. Sasi Gangiah

Lecturer,

Department of hospitality and tourism

DURBAN UNIVERSITY OF TECHNOLOGY

INTERVIEW SCHEDULE FOR FOOD SERVICE WORKERS

A. **Personal information** (Demographics)

1. Name__________________
2. Age_____________
3. Gender : Male/Female
4. Race:
5. Height______________cm
6. Weight_______________kg
7. BMI_____________kg/m^2
8. Job position______________________
9. Type of main job:
10. Years of employment :
11. Working hours:
12. Tenure: full-time / part-time
13. Shift : day shift / split shift / evening shift / any other
14. Tasks
    ____
    ____
    ____
15. How would you describe the weather today:
16. What type of weather were you expecting today (outside):
17. Are you comfortable with weather in Durban?
18. Do you like Durban weather?
19. Do you maintain a comfortable life style?
20. Do you use an air-conditioner in your residence?
21. Do you drive a car to work?
22. How many years have you spent in the kitchen cooking?
23. How many meals are prepared in a single shift?
24. Are there adequate cooling sources in your kitchen?
25. Do you use make up while working in the kitchen?
    Observation---
26. Do you feel comfortable working in your chef's uniform?
    Observation--
27. Do you feel comfortable working in the kitchen with makeup/foundation?
    Observation--
28. Do you have elaborate synthetic hair/wool on your head?
    Observation--
29. Do you feel comfortable with excess hair to work in the kitchen?

30. Do you think less hair/ clean shaven head will be comfortable to work in the kitchen?
31. What is your ethnicity/cultural background?
32. Type of nose----------------------------------
33. Skin tone---------------------------------------
34. Are you suffering from any chronic disease/illness
35. What physical activity are you involved with and how often do you indulge in these activities:

Frequency Activity	Everyday	3-4 times/ week	Twice a week	Once a week	Never
Walking					
Jogging					
Running					
Cycling					
Swimming					
Physical exercise-gym					
Swimming					
Any other					

36. Do you think you possess physical fitness?
37. Did you expect today to be a hot day?
38. Why did you expect/ did not today to be a hot day?
39. From your past experience do you expect summer months to be hot like this

B. Indoor Environmental Quality adapted from CBE occupant survey database (Kim *et al.*2009:247)

Variables	**Factors**	**Questions**
Thermal comfort	Temperature	How is the heat at your workplace? 1. How would you describe the heat during peak periods? 2. Do you feel comfortable cooking with gas stove or with electric stove? Why? 3. Do you experience radiant heat when cooking with traditional clay ovens

Ventilation	Air quality	4. How is the air quality in your workplace(i.e. stuffy / stale air / cleanliness / odours)?
	Air movement	5. How is the ventilation in your kitchen? (inadequate / satisfactory)
	Humidity	6. How is the humidity in your kitchen? (dry / comfortable / very humid) 7. Is there more smoke and fumes during rush/peak period in the kitchen? 8. Do you feel any change in ventilation in kitchen while cooking with gas stove or electric stove? 9. Have you seen any mould growth on kitchen walls or floors?
Lighting	Amount of light	10. What do you feel about the amount of light at your workplace?
	Visual comfort	11. How is visual comfort at your workplace (i.e. glare, reflections, contrast)? 12. Have lighting adjustments made for people with visual limitations? 13. Is there local lighting for close work to reduce eye strain and fatigue? 14. Are the lighting needs of older workers met? 15. Is there good general illumination throughout the kitchen? 16. Do you have any lights in kitchen that flicker? 17. Does the flicker disturb you? 18. Is there regular cleaning and maintenance of lights and windows?
Acoustic quality	Noise level	19. Was a noise measurement programme of exposure carried out?
	Sound level	20. How is the sound level at your workplace (ability to talk to your colleague/neighbour without shouting)? 21. Do you think that the noise levels in your workplace may affect your hearing? 22. Do people need **to raise** voices to speak with someone one metre away? 23. Do you have to talk to older staff louder because they hear less? 24. Besides cooking activities, what are the other sources of noise in the kitchen? 25. What measures were taken to prevent noise exposure?
Kitchen layout	Amount of space	26. How is the amount of space available for individual work?
	Storage	27. Is the amount of space available adequate for storage of equipment / ingredients?
	Ease of interaction	28. How difficult is it to interact with co- workers in kitchen?
Kitchen design	Equipment	29. How comfortable is the placement of operating equipment /adjustable? (reach easily / stand on toes / stretch awkwardly)?

	Plan	30. What do you think about the workplace design?
Overall satisfaction	Workplace satisfaction	31. How comfortable are you with your personal work-station?

Appendix 3c Food Service Establishment Structured Observation

1. Name of the establishment________________________
2. Date:--
3. Location___________________________
4. Type of kitchen load______________________________
5. Owner____________________________
6. Address______________________________
7. Seating Capacity____________________
8. Number of Employees__________________
9. Type of Organisation: Proprietorship / Partnership /Independent Owner / Chain / Franchise/Corporation /Other

AA. **Structural design & material**	FLOOR	WALL	CEILING
AA.Construction			
1. Kitchen-Preparation area			
2. Cooking area			
3. Dining area			
4. Refrigeration area			
5. Wash area-utensil			
6. Dry food storage			
7. Garbage area			
8. Kitchen	width	length	height
9. No. of staff on duty		staff/space ratio=	
10. Staff uniform-Jacket			
11. Staff hair styles-			
12. Staff chef's hat-			

AB. Facility design and layout- Lighting				
13. .Adequate lighting on food preparation areas				
unsatisfactory				good
1	2	3	4	5
14. Adequate lighting on cooking areas				
unsatisfactory				good
1	2	3	4	5
15. Adequate lighting on dish washing areas				
unsatisfactory				good
1	2	3	4	5
16. Are all lights protected from breakage				
unsatisfactory				good
1	2	3	4	5

17. Adequate artificial light in the evening shift				
unsatisfactory				good
1	2	3	4	5
18. Adequate light during load shedding in the evening				
unsatisfactory				good
1	2	3	4	5
19. Presence of Task Light				
unsatisfactory				good
1	2	3	4	5
20. Presence of Infra-red light				
unsatisfactory				good
1	2	3	4	5
21. Presence of UV light- keeping food hot				
unsatisfactory				good
1	2	3	4	5
22. Type of Lighting				
23. Type of Lamps				
24. Type of Luminaires				
25. Presence of Natural light				
unsatisfactory				good
1	2	3	4	5
26. Presence of skylight				
unsatisfactory				good
1	2	3	4	5
27. Sufficient shielded lights to prevent shadows/dark areas				
unsatisfactory				good
1	2	3	4	5
28. Presence of direct glare				
unsatisfactory				good
1	2	3	4	5
29. Presence of indirect glare				
unsatisfactory				good
1	2	3	4	5
30. Presence of flickering lights				
unsatisfactory				good
1	2	3	4	5
31. Presence of Contrast in kitchen				
unsatisfactory				good
1	2	3	4	5
32. Presence of local light- 33. Windows and skylights whitewashed or shaded to avoid glare? --				

34. Dangerous pieces of equipment and areas well lit to alert employees to the hazards?

----

35. Architectural features of light : describe--

----

36. Light switches are easy to reach

unsatisfactory				good
1	2	3	4	5

BB. Thermal environment

37.a. Sources of heat

Equipment	number	Size/capacity
1.Electic ovens		
2.Gas ovens		
3.Clay ovens		
4.Electic stove		
5.Gas stoves		
5.Pressure fryers		
6.Grillers		
7.Kettles		
8.Fryers		
9.Hot plates		
10.Steamers		
11.Boilers		
12.Hot holding		
13.Others		

37.b. Indirect sources of heat

Equipment	No.	size
1.Refrigerators-domestic		
2.Freezers-domestic		
3.Grinders		
4.Crushers		
5.Wet grinders/stone grinders		
6.Blenders		
7.Food processors		

38. Symptoms of thermal strain among staff

Workers	Symptoms Face-red	Sweating	Uniform is wet-excessive sweating	Swearing	Panting

39. BC. Noise in kitchen

1.Sources of Noise

1. Equipment	Type	Continuous	Intermittent	Fluctuating
Ovens-gas, electric				
Ovens-tandoor, pizza				
Pressure stove				
Stoves				

Fryers				
Sizzlers				
Grillers				
Refrigerators				
Freezers				
Steamers				
boilers				
Food processors				
others				
2. HVAC system				
Fans				
Exhaust				
3.Staff				
Head				
Suppliers				
workers				
Visitors				
4. Other activities				
Vacuum cleaning				
Polishing floor				
Moving equipment/doors				
Micellaneous				

BC. Dishwashing

40. Dishwashing machine- noise

unsatisfactory				good
1	2	3	4	5

41.Dishwashing machine producing heat

1	2	3	4	5

BD. Ventilation

41. Canopy length_______ m
    Width____________________m

42. Number of enclosed sides
43. Total exhaust
44. Number and size of grease filters or extractors
45. Adequate duct sizes and numbers
46. Canopy overhang
47. Dish machine exhaust system-
48. Cooking bank hood
49. Pizza hood or tandoor hood or low-side wall hood
50. Make-up air system
51. Interlocked with exhaust system
52. Mixed mode ventilation
53. Fresh air supply through HVAC
54. Make-up diffusers area & velocity
55. Number of Fans__________ Type___________
56. No. of cooling sources
57. Type of cooling sources
58. Natural ventilation

unsatisfactory				good
1	2	3	4	5

59. Number and size of windows				
60. Number and size of doors				
61. Air leakage into the kitchen from closed doors				
62. Air leakage from closed windows				
63. Floor is Dry / semi-wet / wet				
64. Chemicals stored separately-fumes can add to ventilation problem				
BE. Water Supply				
65. Number of taps				
66. Leaking taps-add to humidity				
BF. Facilities-adjustment and cleaning				
67. Adjusting Thermostatic Controls				
unsatisfactory				good
1	2	3	4	5
68. Adjusting Ventilating Equipment				
unsatisfactory				good
1	2	3	4	5
69. Adjusting Fans				
unsatisfactory				good
1	2	3	4	5
70. Air duct clean				
unsatisfactory				good
1	2	3	4	5
71. Fans clean				
unsatisfactory				good
1	2	3	4	5
72. Lights clean				
unsatisfactory				good
1	2	3	4	5
73. Light fixtures clean				
unsatisfactory				good
1	2	3	4	5
74. Mopping Floors clean				
unsatisfactory				good
1	2	3	4	5
75. Gas cylinders stored away from kitchen				
unsatisfactory				good
1	2	3	4	5
76. Gas stoves in good repair				
unsatisfactory				good
1	2	3	4	5
77. Ovens, cookers in good repair				
unsatisfactory				good
1	2	3	4	5
78. Any equipment producing too much soot				
unsatisfactory				good
1	2	3	4	5

79. Frequency of filtering oil				
80. Frequency of change oil in fryer				
CB. Food Service System				
81. Conventional/ cook-chill / ready prepared / Commissary				
82. Type of menu				
83. Cuisine				
84. Number of meals /day				
85. Size OF Ovens				
86. Size of burners on gas stove				
87. Presence of pressure burners				
CB. Pest Control				
88. Presence of mesh/screens at doors				
unsatisfactory				good
1	2	3	4	5
89. Windows are screened to protect from dust/insects				
unsatisfactory				good
1	2	3	4	5

DA. Environmental Measures Ergonomics

90. Humidity levels

Receiving	Preparation	Stove	Oven	Holding	Dishwashing	Corridor	Other

91. Noise levels-different areas

Receiving	Preparation	Stove	Oven	Holding	Dishwashing	Corridor	Outside

92. Light levels-different areas

Receiving	Preparation	Stove	Oven	Holding	Dishwashing	Corridor	Other

93. Air temperature (°C) -outside

94. 95. Ambient temperature (°C) -before starting shift

Receiving	Preparation	Stove	Oven	Holding	Dishwashing	Corridor	Other

95. Ambient temperature (°C) -peak period

Receiving	Preparation	Stove	Oven	Holding	Dishwashing	Corridor	Other

96. Operative temperatures (°C) -1.2m height

Receiving	Preparation	Stove	Oven	Holding	Dishwashing	Corridor	Other

97. Wet bulb globe temperature

Receiving	Preparation	Stove	Oven	Holding	Dishwashing	Corridor	Other

98. Black globe temperature

Receiving	Preparation	Stove	Oven	Holding	Dishwashing	Corridor	Other

99. Air velocity m/s

Receiving	Preparation	Stove	Oven	Holding	Dishwashing	Corridor	Other

100. Carbon dioxide levels ppm

Receiving	Preparation	Stove	Oven	Holding	Dishwashing	Corridor	Other

101. Oxygen levels %

Receiving	Preparation	Stove	Oven	Holding	Dishwashing	Corridor	Other

102. Discomfort index

Receiving	Preparation	Stove	Oven	Holding	Dishwashing	Corridor	Other

Appendix 4 Uniform worn by kitchen workers

Uniform	Frequency	Per cent
White Chef's Jacket	33	19.41
Navy Blue Chef's Jacket	4	2.30
Black Chef's Jacket	4	2.30
Grey Chef's Jacket	4	2.30
Purple Chef's Jacket	3	7.76
Blue Chef's Jacket	2	1.17
Yellow Chef's Jacket	1	0.58
Housecoat	6	3.50
T-shirt any colour	66	38.80
Golf shirt	20	11.76
Purple T-shirt	10	5.88
Formal shirt	6	3.50
Casual wear	11	6.40
Total	170	

Appendix 5 Comfortable in uniform

Response	Frequency	Percent
Yes	138	81.7
No	31	18.3
Total	169	100.0

Appendix 6 Workers' opinion on their hairstyles

			Do you feel comfortable with excess hair to work in the kitchen?			Total
			Yes	No	sometimes/may be	
Do you think less hair/ clean shaven head will be comfortable to work in the kitchen?	Yes	Count	30	104	2	136
		% within Do you think less hair/ clean shaven head will be comfortable to work in the kitchen?	22.1 %	76.5 %	1.5 %	100.0 %
		% within Do you feel comfortable with excess hair to work in the kitchen?	61.2 %	93.7 %	100.0 %	84.0 %
		% of Total	18.5 %	64.2 %	1.2 %	84.0 %
	No	Count	15	7	0	22
		% within Do you think less hair/ clean shaven head will be comfortable to work in the kitchen?	68.2 %	31.8 %	0.0 %	100.0 %
		% within Do you feel comfortable with excess hair to work in the kitchen?	30.6 %	6.3 %	0.0 %	13.6 %
		% of Total	9.3 %	4.3 %	0.0 %	13.6 %
	Some-times/ May be	Count	4	0	0	4
		% within Do you think less hair/ clean shaven head will be comfortable to work in the kitchen?	100.0 %	0.0 %	0.0 %	100.0 %
		% within Do you feel comfortable with excess hair to work in the kitchen?	8.2 %	0.0 %	0.0 %	2.5 %
		% of Total	2.5 %	0.0 %	0.0 %	2.5 %
Total		Count	49	111	2	162
		% within Do you think less hair/ clean shaven head will be comfortable to work in the kitchen?	30.2 %	68.5 %	1.2 %	100.0 %
		% within Do you feel comfortable with excess hair to work in the kitchen?	100.0 %	100.0 %	100.0 %	100.0 %
		% of Total	30.2 %	68.5 %	1.2 %	100.0 %

Appendix 7 Hair Styles among kitchen workers

Staff hair styles	**Percent**
Clean shaven	12.8
Dreadlocks	13.6
Extension	13.6
Natural hair	45
Weave	15

Appendix 8 Body stature and somatotypes among kitchen workers

Phenotype and Genotype of kitchen staff							
Ethnicity	N	Zulu	Xhosa	Other Africans	Indian	White (Caucasians)	Coloured (Mix Race)
Male	65	49	1	2	9	1	0
Female	109	83	4	1	5	0	1
Body stature		Lean	Normal	Obese	Morbidly obese		
Male	65	12	40	15	1		
Female	109	7	34	60	8		
Body Type		Ectomorph	Mesomorph	Endomorph			
Male	65	12	40	10			
Female	109	7	34	60			

Appendix 9 Skin colour among kitchen workers

Skin tone	Frequency	Percent
Very fair	5.0	2.9
Fair	10	5.8
Medium fair	22	12.94
Medium brown	93	54.7
Medium dark	11	6.47
Dark	24	14.11
Black	5	2.9

Appendix 10 Type of nose among kitchen workers

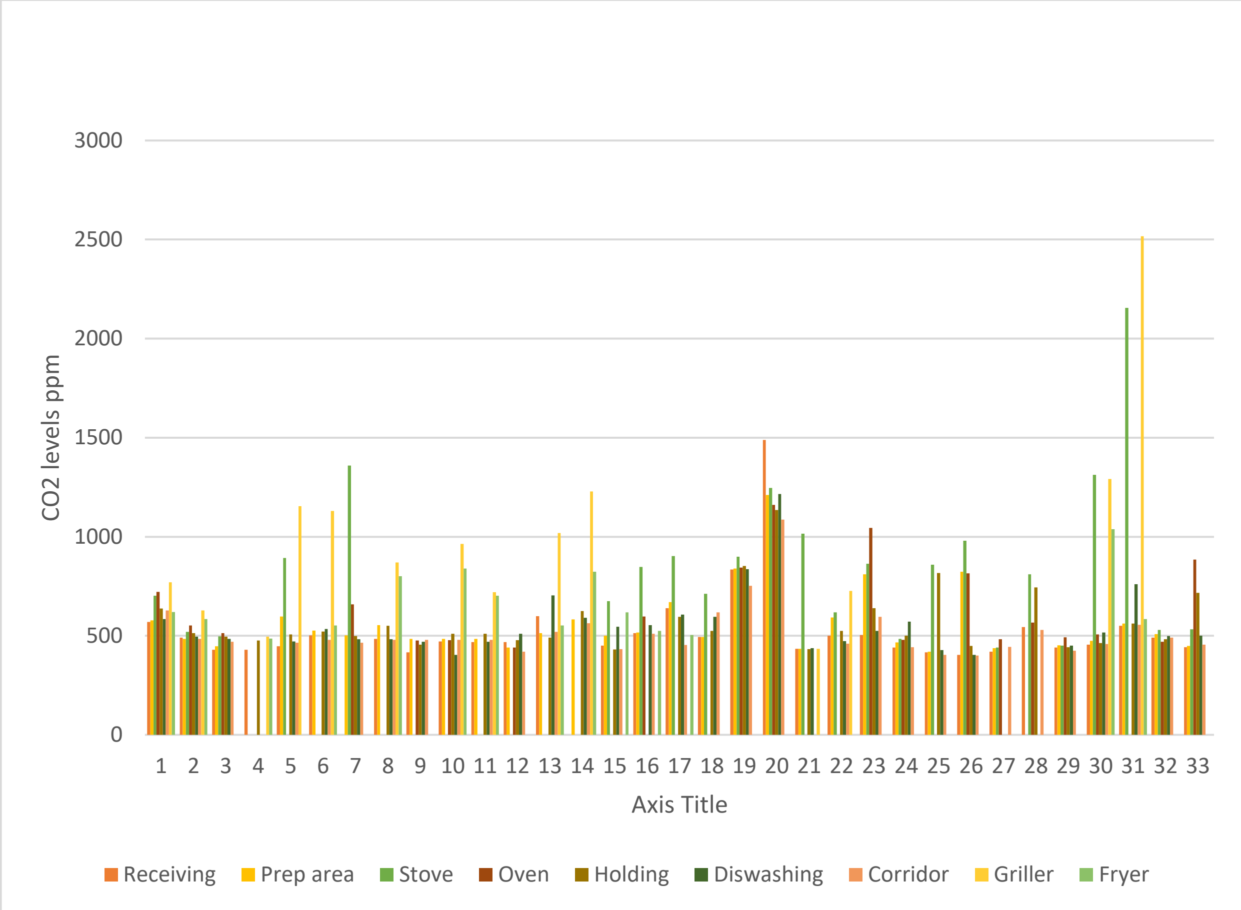
Type of nose	Frequency	Percent
Big large	9	5.2
Button	3	1.8
Droopy	6	3.5
Funnel	109	64.4
Greuan	1	0.5
Hooked	2	1.1
Medium normal	10	5.9
Small nose	3	1.8
Snub	14	8.2
Straight	4	2.3
Upturned	7	4.1

Appendix 11 Mean airflow (m/s) in the sample kitchens

	Kitchen areas						
Type of kitchen	**Receiving**	**Preparation**	**Cooking**	**Oven**	**Holding**	**Dishwashing**	**Corridor**
Light-duty	**0.05**	0.30	-	0.30	0.05	0.10	0.10
Trimmed mean	**0.10**	**0.40**	**-**	**0.50**	**0.10**	**0.10**	**0.10**
Medium-duty	0.24	0.20	0.22	0.25	0.12	0.10	0.32
Trimmed mean	**0.40**	**0.30**	**0.30**	**0.30**	**0.20**	**0.20**	**0.40**
Heavy-duty	0.37	0.38	0.42	0.07	0.14	0.10	0.53
Trimmed mean	**1.0**	**0.40**	**0.30**	**0.30**	**0.10**	**0.10**	**1.0**
Extra-heavy duty	0.47	**0.05**	0.17	0.17	0.13	0.22	**0.63**
Trimmed mean	**0.30**	**0.20**	**0.20**	**0.20**	**0.1**	**0.1**	**0.30**

Appendix 12 Head chefs' opinion on ventilation in kitchens

Opinion	**Frequency**	**Percent**
Inadequate	4	11.8
Satisfactory	23	67.6
Good	6	**20.6**
Total	33	100.0



Appendix 13 Mean CO_2 levels in kitchens

Appendix 14 Mean relative humidity values of study kitchens

Kitchen areas	Mean RH%	Trimmed mean RH%	Difference
Receiving	56.01	42.77	13.9
Preparation	**55.93**	**51.17**	**4.76**
Stove	**58.62**	**51.30**	**7.32**
Oven	55.52	50.23	5.29
Holding	53.12	50.91	2.21
Dish washing	**54.73**	**51.40**	**33.3**
Corridor	52.30	41.69	10.60
Fryer	54.17	49.85	4.67
Griller	59.28	52.37	6.91

Appendix 15 Association between foodservice variables

Style of service	Type of kitchen load	Cuisine	Test	Value	df	Asymptotic Significance (2-sided)
Q13.6=Quick service	Medium-duty	-	Fisher's Exact	9.265	1	0.013
Q13.1=Family restaurant	Heavy-duty	Indian	Pearson Chi-Square	4.202	1	0.04
Q13.1=Family restaurant	Extra-heavy duty	Indian	Pearson Chi-Square	4.00	1	0.046
Q13.7=Fine dining	Extra-heavy duty	Indian	Pearson Chi-Square	4.00	1	0.046
Q13.1=Family restaurant	Extra-heavy duty	Italian	Pearson Chi-Square	4.00	1	0.046
Q13.7=Fine dining	Extra-heavy duty	Italian	Pearson Chi-Square	4.00	1	0.046
Q13.4=Coffee shop	Heavy-duty	**Fusion**	Pearson Chi-Square	5.775	1	0.016
Q13.7=Fine dining	Heavy-duty	**Fusion**	Pearson Chi-Square	5.324	1	0.021
Q13.5=Cafeteria style	Medium-duty	Continental	Pearson Chi-Square	5.00	1	0.025
Q13.7=Fine dining	Heavy-duty	Oriental /Thai	Pearson Chi-Square	3.850	1	0.05

Appendix 16 Frequency of cleaning extractors

Time	Frequency	Percent	Valid Percent	Cumulative Percent
Weekly	2	6.0	6.0	6.0
Monthly	8	24.2	24.2	30.2
Quarterly	5	15.1	15.1	45.3
Bi-annual	17	51.5	51.5	97.0
Yearly	1	3.0	3.0	100.0
Total	33	100.0	100.0	

Appendix 17 Noise levels (dBA) in different foodservice establishments

Type of kitchen	Casual	Institutional	QSR
Receiving	66.04	65.66	66.69
Preparation area	70.45	70.94	**71.43**
Stove	78.50	76.17	74.41
Oven	67.41	68.15	68.16
Holding	69.57	70.27	**80.56**
Dishwashing	**75.85**	74.10	71.22
Corridor	68.18	67.53	68.04
Fryer	62.17	64.25	68.79

Appendix 18 Head chef ranking of equipment noise

Equipment	Weighted Mean
HVAC & fans	2.2
Refrigeration	2.9
Swivelling doors	3.1
Grinders and blenders	3.5
Boilers and steamers	3.7
Gas stoves	3.8
Fryers	3.8
Trolleys	4.0
Dishwasher	4.1
Air-conditioner	4.5
Ovens	4.6

Appendix 19 Goodness of fit on maintenance issues

Questions	Chi-Square	df	Asymp. Sig.	Exact Sig.	Point Probability
Sweeping and dusting in kitchen increase dust and particulate matter in the air	16.941	1	0.000	0.000	0.000
Amount of fumes, mist and smoke vary during the day	0.758	1	0.384	0.487	0.191
Adequate measures to extract particulate matter during repairs, installation or construction in kitchen	11.765	1	0.001	0.001	0.001
Contaminated outdoor air leak into your kitchens through your doors/ windows	19.882	1	0.000	0.000	0.000
Kitchen room temperature control	23.059	1	0.000	0.000	0.000
Measures to prevent excessive noise	25.485	1	0.000	0.000	0.000
All the kitchen equipment is in good repair	33.529	3	0.000	0.000	0.000

Appendix 20 Waiting period for repair or replace equipment

Waiting Period	Frequency	Percent
24 hours	10	30.3
One week	13	39.4
Fortnight	4	12.1
One month	6	18.2
Total	33	100.0

Appendix 21 Kitchen equipment installed as per specification

Opinions		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Never	1	2.9	2.9	2.9
	Rarely	2	5.9	5.9	8.8
	Sometimes	1	2.9	2.9	11.8
	Fairly Often	4	11.8	11.8	23.5
	Very Often	26	76.5	76.5	100.0
	Total	34	100.0	100.0	

Appendix 22 Disturbance from flicker

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	1	0.6	7.7	7.7
	No	12	7.0	92.3	100.0
	Total	13	7.6	100.0	
Missing	System	158	92.4		
Total		170	100.0		

Appendix 23 Presence of indirect glare

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	unsatisfactory	2	6.1	6.7	6.7
	somewhat satisfactory	3	9.1	10.0	16.7
	neutral	4	12.1	13.3	30.0
	fairly good	11	33.3	36.7	66.7
	good	10	30.3	33.3	100.0
	Total	30	90.9	100.0	
Missing	System	3	9.1		
Total		33	100.0		

Appendix: 24 Cross tabulation of interview schedule

Questions			Tenure	Race	Job position	Gender	How would you describe the weather today?	How many meals are prepared in a single shift?
Are you comfortable with weather in Durban?								
Fisher's Exact Test	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)		0.008				
Do you like Durban weather? * Tenure								
Fisher's Exact Test	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)		0.012				
Do you maintain a comfortable life style? * Race								
Fisher's Exact Test	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)		0.0001				
Do you use an air-conditioner in your residence? * Race								
Fisher's Exact Test	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)		0.0001				
Do you drive a car to work? * Job position								
Fisher's Exact Test	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)		0.054				
Do you use make up while working in the kitchen? * Gender								
Fisher's Exact Test	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)		0.000				
Observation on makeup * Gender								
Fisher's Exact Test	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)		0.008				
Do you maintain a comfortable life style? * How would you describe the weather today?								
Fisher's Exact Test	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)		0.046				
Do you drive a car to work? * How would you describe the weather today?								
Fisher's Exact Test	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)		0.039				
Do you feel comfortable working in your chef's uniform? * How many meals are prepared in a single shift?								
Fisher's Exact Test	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)		0.045				
Observation on uniform * How many meals are prepared in a single shift?								
Fisher's Exact Test	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)		0.000				
Observation on makeup * Do you use an air-conditioner in your residence?								
Fisher's Exact Test	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)		0.050				
What is your ethnicity/cultural background? * Do you maintain a comfortable life style?								
Fisher's Exact Test	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)		0.001				
What is your ethnicity/cultural background? * Do you use an air-conditioner in your residence?								
Fisher's Exact Test	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)		0.001				
What is your ethnicity/cultural background? * Do you drive a car to work?								
Fisher's Exact Test	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)		0.001				
Type of nose * Do you maintain a comfortable life style?								
Fisher's Exact Test	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)		0.001				
Type of nose * Are you comfortable with weather in Durban?								
Fisher's Exact Test	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)		0.001				
Skin tone * Do you maintain a comfortable life style?								
Fisher's Exact Test	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)		0.001				

Are you suffering from any chronic disease/illness? * Do you use an air-conditioner in your residence?

Fisher's Exact Test	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	0.040

Walking * Do you maintain a comfortable life style?

Fisher's Exact Test	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	0.002

Walking * Do you drive a car to work?

Fisher's Exact Test	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	0.007

Swimming * Do you drive a car to work?

Fisher's Exact Test	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	0.079

Do you think you possess physical fitness? * Do you maintain a comfortable life style?

Fisher's Exact Test	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	0.005

From your past experience do you expect summer months to be hot like this? * Do you maintain a comfortable life style?

Fisher's Exact Test	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	0.040

How would you describe the heat during peak periods? * Do you maintain a comfortable life style?

Fisher's Exact Test	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	0.039

Do you feel comfortable working in the kitchen with make up/foundation? * BMI

Fisher's Exact Test	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	0.050

Do you have elaborate synthetic hair/wool on your head? * BMI

Fisher's Exact Test	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	0.028

Do you feel comfortable with excess hair to work in the kitchen? * BMI

Fisher's Exact Test	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	0.012

Do you think you possess physical fitness? * BMI

Fisher's Exact Test	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	0.025

Shift * BMI

Fisher's Exact Test	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	0.033

Gender * BMI

Fisher's Exact Test	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	0.001

Appendix: 25 Spearman's correlation of observation schedule with observation schedule

		Adequate lighting on dish washing areas	Are all lights protected from breakage	Adequate artificial light at night	Adequate light during load shedding at night	Presence of Task Light	Presence of Infra-red light	Presence of UV light-keeping food hot	Presence of Natural light	Presence of skylight	Sufficient shielded lights to prevent shadows/dark areas	Presence of direct glare	Presence of indirect glare	Presence of flickering lights	Presence of Contrast in kitchen
Adequate lighting on food preparation areas	Correlation Coefficient	.553**	0.182	.597**	.428*	0.391	-0.025	0.345	0.290	0.148	.632**	0.273	0.180	.544**	.544**
	Sig. (2-tailed)	0.001	0.328	0.001	0.033	0.080	0.934	0.161	0.135	0.533	0.000	0.186	0.349	0.002	0.002
	N	32	31	30	25	21	14	18	28	20	29	25	29	29	29
Adequate lighting on cooking areas	Correlation Coefficient	.661**	.411*	.439*	0.395	.499*	0.361	0.251	0.242	0.216	.425*	0.217	0.041	.466*	.466*
	Sig. (2-tailed)	0.000	0.022	0.015	0.050	0.021	0.205	0.316	0.214	0.361	0.022	0.296	0.834	0.011	0.011
	N	32	31	30	25	21	14	18	28	20	29	25	29	29	29
Adequate lighting on dish washing areas	Correlation Coefficient	1.000	.537**	.418*	0.153	.553**	0.268	0.144	.400*	0.232	.441*	0.162	0.193	.418*	.418*
	Sig. (2-tailed)		0.002	0.022	0.466	0.009	0.354	0.568	0.035	0.325	0.017	0.439	0.317	0.024	0.024
	N	32	31	30	25	21	14	18	28	20	29	25	29	29	29
Are all lights protected from breakage	Correlation Coefficient	.537**	1.000	.401*	0.200	.480*	0.475	0.183	0.074	-0.059	.396*	0.169	-0.208	0.237	0.237
	Sig. (2-tailed)	0.002		0.026	0.328	0.024	0.074	0.452	0.702	0.799	0.030	0.410	0.271	0.207	0.207
	N	31	32	31	26	22	15	19	29	21	30	26	30	30	30
Adequate artificial light at night	Correlation Coefficient	.418*	.401*	1.000	.753**	.450*	0.021	.615**	0.093	-0.394	0.313	0.247	-0.075	0.266	0.266
	Sig. (2-tailed)	0.022	0.026		0.000	0.036	0.941	0.005	0.637	0.086	0.098	0.233	0.698	0.164	0.164
	N	30	31	31	26	22	15	19	28	20	29	25	29	29	29
Adequate light during load shedding at night	Correlation Coefficient	0.153	0.200	.753**	1.000	.482*	0.119	0.427	-0.147	-0.375	-0.045	-0.076	-0.343	-0.025	-0.025
	Sig. (2-tailed)	0.466	0.328	0.000		0.027	0.672	0.087	0.492	0.138	0.835	0.743	0.093	0.907	0.907
	N	25	26	26	26	21	15	17	24	17	24	21	25	25	25
Presence of Task Light	Correlation Coefficient	.553**	.480*	.450*	.482*	1.000	.899**	0.485	-0.097	-0.160	0.315	0.254	-0.227	0.261	0.261
	Sig. (2-tailed)	0.009	0.024	0.036	0.027		0.000	0.057	0.684	0.570	0.165	0.325	0.322	0.253	0.253
	N	21	22	22	21	22	14	16	20	15	21	17	21	21	21
Presence of Infra-red light	Correlation Coefficient	0.268	0.475	0.021	0.119	.899**	1.000	0.365	-0.225		0.228	0.145	-0.161	-0.184	-0.184
	Sig. (2-tailed)	0.354	0.074	0.941	0.672	0.000		0.243	0.440		0.434	0.621	0.566	0.529	0.529
	N	14	15	15	15	14	15	12	14	11	14	14	15	14	14
Presence of UV light-	Correlation Coefficient	0.144	0.183	.615**	0.427	0.485	0.365	1.000	-0.015		0.104	0.078	-0.343	0.053	0.053

keeping food hot	Sig. (2-tailed)	0.568	0.452	0.005	0.087	0.057	0.243		0.954		0.673	0.775	0.151	0.834	0.834
	N	18	19	19	17	16	12	19	17	15	19	16	19	18	18
Presence of Natural light	Correlation Coefficient	.400*	0.074	0.093	-0.147	-0.097	-0.225	-0.015	1.000	0.352	0.241	0.326	.434*	0.215	0.215
	Sig. (2-tailed)	0.035	0.702	0.637	0.492	0.684	0.440	0.954		0.128	0.217	0.120	0.024	0.282	0.282
	N	28	29	28	24	20	14	17	29	20	28	24	27	27	27
Presence of skylight	Correlation Coefficient	0.232	-0.059	-0.394	-0.375	-0.160			0.352	1.000	0.233	0.102	0.271	0.148	0.148
	Sig. (2-tailed)	0.325	0.799	0.086	0.138	0.570			0.128		0.309	0.679	0.234	0.534	0.534
	N	20	21	20	17	15	11	15	20	21	21	19	21	20	20
Sufficient shielded lights to prevent shadows/dark areas	Correlation Coefficient	.441*	.396*	0.313	-0.045	0.315	0.228	0.104	0.241	0.233	1.000	0.391	.452*	.687**	.687**
	Sig. (2-tailed)	0.017	0.030	0.098	0.835	0.165	0.434	0.673	0.217	0.309		0.054	0.016	0.000	0.000
	N	29	30	29	24	21	14	19	28	21	30	25	28	28	28
Presence of direct glare	Correlation Coefficient	0.162	0.169	0.247	-0.076	0.254	0.145	0.078	0.326	0.102	0.391	1.000	0.212	0.202	0.202
	Sig. (2-tailed)	0.439	0.410	0.233	0.743	0.325	0.621	0.775	0.120	0.679	0.054		0.299	0.334	0.334
	N	25	26	25	21	17	14	16	24	19	25	26	26	25	25
Presence of indirect glare	Correlation Coefficient	0.193	-0.208	-0.075	-0.343	-0.227	-0.161	-0.343	.434*	0.271	.452*	0.212	1.000	.375*	.375*
	Sig. (2-tailed)	0.317	0.271	0.698	0.093	0.322	0.566	0.151	0.024	0.234	0.016	0.299		0.045	0.045
	N	29	30	29	25	21	15	19	27	21	28	26	30	29	29
Presence of flickering lights	Correlation Coefficient	0.084	0.090	.468*	0.304	0.202	-.674*	0.336	0.165	0.056	0.209	.469*	0.223	.435*	.435*
	Sig. (2-tailed)	0.676	0.648	0.014	0.158	0.406	0.016	0.203	0.432	0.821	0.305	0.021	0.263	0.021	0.021
	N	27	28	27	23	19	12	16	25	19	26	24	27	28	28
Presence of contrast in the kitchen	Correlation Coefficient	.418*	0.237	0.266	-0.025	0.261	-0.184	0.053	0.215	0.148	.687**	0.202	.375*	1.000	1.000
	Sig. (2-tailed)	0.024	0.207	0.164	0.907	0.253	0.529	0.834	0.282	0.534	0.000	0.334	0.045		
	N	29	30	29	25	21	14	18	27	20	28	25	29	30	30

Light switches are easy to reach	Correlation Coefficient	Adequate lighting on cooking areas	Adequate lighting on dish washing areas	Are all lights protected from breakage	Adequate artificial light at night	Adequate light during load shedding at night	Presence of Task Light	Presence of Infra-red light	Presence of UV light-keeping food hot	Presence of Natural light	Presence of skylight	Sufficient shielded lights to prevent shadows /dark areas	Presence of direct glare	Presence of indirect glare	Presence of flickering lights	Presence of Contrast in kitchen
	Sig. (2-tailed)	.435*	0.322	0.192	.461*	.443*	0.203	0.161	0.331	-0.018	0.072	0.164	0.349	-0.121	0.247	0.146
	N	0.016	0.083	0.301	0.010	0.027	0.377	0.566	0.166	0.929	0.755	0.396	0.080	0.525	0.214	0.449
Dishwashing machine- noise	Correlation Coefficient	30	30	31	30	25	21	15	19	28	21	29	26	30	27	29
	Sig. (2-tailed)	-0.295	-0.217	-.787**	-.781**	-0.187	-0.404	-0.531	-0.642	-.892**		-0.252	-0.196	-0.132	-0.380	-0.128
	N	0.351	0.498	0.004	0.005	0.606	0.247	0.278	0.086	0.001		0.483	0.642	0.717	0.313	0.724
Dishwashing machine producing heat	Correlation Coefficient	12	12	11	11	10	10	6	8	9	8	10	8	10	9	10
	Sig. (2-tailed)	0.264	0.115	-0.042	-0.021	-0.061	-0.322	-0.707	-0.183	-0.243		0.293	0.081	-0.020	0.107	-0.092
	N	0.493	0.769	0.922	0.961	0.897	0.481	0.182	0.695	0.600		0.482	0.864	0.963	0.841	0.844
Natural ventilation	Correlation Coefficient	9	9	8	8	7	7	5	7	7	7	8	7	8	6	7
	Sig. (2-tailed)	0.186	0.085	0.031	0.039	-0.159	-0.141	-0.282	-0.133	.455*	0.107	0.375	0.392	0.137	-0.036	0.166
	N	0.352	0.674	0.882	0.854	0.504	0.591	0.400	0.650	0.025	0.683	0.065	0.079	0.522	0.869	0.429
Adjusting Thermostatic Controls	Correlation Coefficient	27	27	26	25	20	17	11	14	24	17	25	21	24	24	25
	Sig. (2-tailed)	0.166	0.226	0.350	0.293	0.116	0.059	-0.258	-0.194	0.216	-0.108	-0.180	0.214	-0.016	0.161	0.034
	N	0.408	0.257	0.080	0.155	0.606	0.821	0.418	0.506	0.322	0.668	0.400	0.338	0.940	0.443	0.870
Adjusting Ventilating Equipment	Correlation Coefficient	27	27	26	25	22	17	12	14	23	18	24	22	25	25	26
	Sig. (2-tailed)	0.112	0.103	0.183	0.319	0.116	0.059	-0.258	-0.194	0.034	-0.108	-0.076	0.214	-0.016	0.161	0.034
	N	0.571	0.602	0.361	0.112	0.606	0.821	0.418	0.506	0.875	0.668	0.720	0.338	0.940	0.443	0.870
Adjusting Fans	Correlation Coefficient	28	28	27	26	22	17	12	14	24	18	25	22	25	25	26
	Sig. (2-tailed)	-0.108	-0.028	-0.112	0.177	-0.008	-0.124	-0.417	-0.593	0.247	0.246	0.131	.572*	0.412	.580*	0.154
	N	0.669	0.911	0.658	0.496	0.980	0.717	0.352	0.121	0.324	0.441	0.616	0.033	0.101	0.019	0.554
Air duct clean	Correlation Coefficient	18	18	18	17	13	11	7	8	18	12	17	14	17	16	17
	Sig. (2-tailed)	-0.057	-0.017	-0.075	0.311	.423*	-0.073	-0.074	0.142	-0.003	-0.148	-0.179	-0.015	-0.060	0.157	-.460*
	N	0.762	0.928	0.690	0.095	0.035	0.754	0.801	0.574	0.986	0.534	0.354	0.943	0.757	0.425	0.011
Fans clean	Correlation Coefficient	31	31	31	30	25	21	14	18	28	20	29	25	29	28	30
	Sig. (2-tailed)	0.352	0.330	.671*	.594*	0.401	0.000	-0.272	0.125	0.331	0.366	0.398	0.479	-0.094	0.545	0.083
	N	0.238	0.271	0.012	0.041	0.325	1.000	0.728	0.841	0.270	0.333	0.177	0.136	0.772	0.067	0.797

Lights clean	Correlation Coefficient	13	13	13	12	8	8	4	5	13	9	13	11	12	12	12
	Sig. (2-tailed)	.592**	.411*	.525**	0.270	0.218	0.395	0.464	0.236	0.197	0.193	.456*	.465*	-0.200	0.202	0.156
	N	0.001	0.024	0.003	0.157	0.305	0.076	0.095	0.362	0.325	0.428	0.015	0.022	0.307	0.312	0.418
Light fixtures clean	Correlation Coefficient	30	30	30	29	24	21	14	17	27	19	28	24	28	27	29
	Sig. (2-tailed)	.371*	0.200	.554**	.446*	.407*	.507*	.536*	0.422	0.026	-0.380	0.272	0.330	-.393*	0.144	0.025
	N	0.040	0.281	0.001	0.013	0.043	0.019	0.048	0.081	0.895	0.098	0.154	0.107	0.035	0.465	0.896
Mopping Floors clean	Correlation Coefficient	31	31	31	30	25	21	14	18	28	20	29	25	29	28	30
	Sig. (2-tailed)	.599**	0.297	.359*	0.257	0.121	0.176	0.163	0.037	0.061	-0.042	0.348	-0.010	0.037	0.057	0.244
	N	0.000	0.105	0.048	0.171	0.564	0.445	0.578	0.885	0.756	0.860	0.065	0.963	0.848	0.772	0.194
Gas cylinders stored away from kitchen	Correlation Coefficient	31	31	31	30	25	21	14	18	28	20	29	25	29	28	30
	Sig. (2-tailed)	-0.201	0.026	-0.190	-0.131	-0.171	0.157	0.135	-0.238	0.282	0.063	0.186	.461*	0.357	-0.075	-0.143
	N	0.315	0.896	0.343	0.524	0.459	0.520	0.676	0.392	0.181	0.812	0.362	0.027	0.079	0.721	0.487
Gas stoves in good repair	Correlation Coefficient	27	27	27	26	21	19	12	15	24	17	26	23	25	25	26
	Sig. (2-tailed)	0.354	0.102	0.104	0.154	0.395	0.370	0.119	0.450	-0.081		.465*	0.076	-0.277	-0.035	0.271
	N	0.082	0.626	0.621	0.472	0.094	0.144	0.728	0.106	0.721		0.022	0.744	0.202	0.873	0.201
Ovens, cookers in good repair	Correlation Coefficient	25	25	25	24	19	17	11	14	22	15	24	21	23	23	24
	Sig. (2-tailed)	0.378	0.116	-0.105	0.033	0.082	-0.164	-0.561	0.226	0.399		0.192	0.134	0.000	0.146	0.013
	N	0.069	0.591	0.632	0.884	0.731	0.528	0.073	0.438	0.073		0.404	0.597	0.999	0.528	0.952
Any equipment producing too much soot	Correlation Coefficient	24	24	23	22	20	17	11	14	21	15	21	18	22	21	23
	Sig. (2-tailed)	0.286	0.078	0.103	-0.163	-0.119	0.463		0.074	-0.316	0.286	0.330	-0.082	0.289	0.043	0.336
	N	0.235	0.751	0.685	0.518	0.672	0.130		0.839	0.216	0.343	0.196	0.771	0.260	0.865	0.172
	19	19	19	18	18	15	12	5	10	17	13	17	15	17	18	18

Adequate lighting on food preparation areas	Correlation Coefficient	Dish washing machine-noise	Dish washing machine producing heat	Natural ventilation	Adjusting Thermostatic Controls	Adjusting Ventilating Equipment	Adjusting Fans	Air duct clean	Fans clean	Lights clean	Light fixtures clean	Mopping Floors clean	Gas cylinders stored away from kitchen	Gas stoves in good repair	Ovens, cookers in good repair	Any equipment producing too much soot
	Sig. (2-tailed)	-0.213	0.115	0.167	0.033	0.080	0.051	0.122	0.229	.409*	0.267	0.040	-0.136	0.339	0.381	0.091
	N	0.507	0.769	0.406	0.869	0.687	0.841	0.514	0.451	0.025	0.147	0.833	0.500	0.097	0.066	0.712
Adequate lighting on cooking areas	Correlation Coefficient	12	9	27	27	28	18	31	13	30	31	30	27	25	24	19
	Sig. (2-tailed)	-0.295	0.264	0.186	0.166	0.112	-0.108	-0.057	0.352	.592**	.371*	-0.358	-0.201	0.354	0.378	0.286
	N	0.351	0.493	0.352	0.408	0.571	0.669	0.762	0.238	0.001	0.040	0.279	0.315	0.082	0.069	0.235
Adequate lighting on dish washing areas	Correlation Coefficient	12	9	27	27	28	18	31	13	30	31	11	27	25	24	19
	Sig. (2-tailed)	-0.217	0.115	0.085	0.226	0.103	-0.028	-0.017	0.330	.411*	0.200	0.091	0.026	0.102	0.116	0.078
	N	0.498	0.769	0.674	0.257	0.602	0.911	0.928	0.271	0.024	0.281	0.830	0.896	0.626	0.591	0.751
Are all lights protected from breakage	Correlation Coefficient	12	9	27	27	28	18	31	13	30	31	8	27	25	24	19
	Sig. (2-tailed)	-.787**	-0.042	0.031	0.350	0.183	-0.112	-0.075	.671*	.525**	.554**	0.159	-0.190	0.104	-0.105	0.103
	N	0.004	0.922	0.882	0.080	0.361	0.658	0.690	0.012	0.003	0.001	0.428	0.343	0.621	0.632	0.685
Adequate artificial light at night	Correlation Coefficient	11	8	26	26	27	18	31	13	30	31	27	27	25	23	18
	Sig. (2-tailed)	-.781**	-0.021	0.039	0.293	0.319	0.177	0.311	.594*	0.270	.446*	0.224	-0.131	0.154	0.033	-0.163
	N	0.005	0.961	0.854	0.155	0.112	0.496	0.095	0.041	0.157	0.013	0.262	0.524	0.472	0.884	0.518
Adequate light during load shedding at night	Correlation Coefficient	11	8	25	25	26	17	30	12	29	30	27	26	24	22	18
	Sig. (2-tailed)	-0.187	-0.061	-0.159	0.116	0.116	-0.008	.423*	0.401	0.218	.407*	0.292	-0.171	0.395	0.082	-0.119
	N	0.606	0.897	0.504	0.606	0.606	0.980	0.035	0.325	0.305	0.043	0.131	0.459	0.094	0.731	0.672
Presence of Task Light	Correlation Coefficient	10	7	20	22	22	13	25	8	24	25	28	21	19	20	15
	Sig. (2-tailed)	-0.404	-0.322	-0.141	0.059	0.059	-0.124	-0.073	0.000	0.395	.507*	-0.377	0.157	0.370	-0.164	0.463
	N	0.247	0.481	0.591	0.821	0.821	0.717	0.754	1.000	0.076	0.019	0.123	0.520	0.144	0.528	0.130
Presence of Infra-red light	Correlation Coefficient	10	7	17	17	17	11	21	8	21	21	18	19	17	17	12
	Sig. (2-tailed)	-0.531	-0.707	-0.282	-0.258	-0.258	-0.417	-0.074	-0.272	0.464	.536*	0.118	0.135	0.119	-0.561	
	N	0.278	0.182	0.400	0.418	0.418	0.352	0.801	0.728	0.095	0.048	0.521	0.676	0.728	0.073	
Presence of UV light-keeping food hot	Correlation Coefficient	6	5	11	12	12	7	14	4	14	14	32	12	11	11	5
	Sig. (2-tailed)	-0.642	-0.183	-0.133	-0.194	-0.194	-0.593	0.142	0.125	0.236	0.422	0.272	-0.238	0.450	0.226	0.074
	N	0.086	0.695	0.650	0.506	0.506	0.121	0.574	0.841	0.362	0.081	0.368	0.392	0.106	0.438	0.839
Presence of Natural light	Correlation Coefficient	8	7	14	14	14	8	18	5	17	18	13	15	14	14	10

	Sig. (2-tailed)	-.892**	-0.243	.455*	0.216	0.034	0.247	-0.003	0.331	0.197	0.026	.383*	0.282	-0.081	0.399	-0.316
	N	0.001	0.600	0.025	0.322	0.875	0.324	0.986	0.270	0.325	0.895	0.033	0.181	0.721	0.073	0.216
Presence of skylight	Correlation Coefficient	9	7	24	23	24	18	28	13	27	28	31	24	22	21	17
	Sig. (2-tailed)			0.107	-0.108	-0.108	0.246	-0.148	0.366	0.193	-0.380	0.347	0.063			0.286
	N			0.683	0.668	0.668	0.441	0.534	0.333	0.428	0.098	0.051	0.812			0.343
Sufficient shielded lights to prevent shadows/dark areas	Correlation Coefficient	8	7	17	18	18	12	20	9	19	20	32	17	15	15	13
	Sig. (2-tailed)	-0.252	0.293	0.375	-0.180	-0.076	0.131	-0.179	0.398	.456*	0.272	1.000	0.186	.465*	0.192	0.330
	N	0.483	0.482	0.065	0.400	0.720	0.616	0.354	0.177	0.015	0.154		0.362	0.022	0.404	0.196
Presence of direct glare	Correlation Coefficient	10	8	25	24	25	17	29	13	28	29	32	26	24	21	17
	Sig. (2-tailed)	-0.196	0.081	0.392	0.214	0.214	.572*	-0.015	0.479	.465*	0.330	-0.249	.461*	0.076	0.134	-0.082
	N	0.642	0.864	0.079	0.338	0.338	0.033	0.943	0.136	0.022	0.107	0.201	0.027	0.744	0.597	0.771
Presence of indirect glare	Correlation Coefficient	8	7	21	22	22	14	25	11	24	25	28	23	21	18	15
	Sig. (2-tailed)	-0.132	-0.020	0.137	-0.016	-0.016	0.412	-0.060	-0.094	-0.200	-.393*	0.318	0.357	-0.277	0.000	0.289
	N	0.717	0.963	0.522	0.940	0.940	0.101	0.757	0.772	0.307	0.035	0.121	0.079	0.202	0.999	0.260
Presence of flickering lights	Correlation Coefficient	10	8	24	25	25	17	29	12	28	29	25	25	23	22	17
	Sig. (2-tailed)	-0.380	0.107	-0.036	0.161	0.161	.580*	0.157	0.545	0.202	0.144	.559**	-0.075	-0.035	0.146	0.043
	N	0.313	0.841	0.869	0.443	0.443	0.019	0.425	0.067	0.312	0.465	0.005	0.721	0.873	0.528	0.865
Presence of contrast in the kitchen	Correlation Coefficient	9	6	24	25	25	16	28	12	27	28	24	25	23	21	18
	Sig. (2-tailed)	-0.128	-0.092	0.166	0.034	0.034	0.154	-.460*	0.083	0.156	0.025	.535*	-0.143	0.271	0.013	0.336
	N	0.724	0.844	0.429	0.870	0.870	0.554	0.011	0.797	0.418	0.896	0.018	0.487	0.201	0.952	0.172
	29	10	7	25	26	26	17	30	12	29	30	19	26	24	23	18

Light switches are easy to reach	Correlation Coefficient	Dishwashing machine- noise	Dishwashing machine producing heat	Natural ventilation	Adjusting Thermostatic Controls	Adjusting Ventilating Equipment	Adjusting Fans	Air duct clean	Fans clean	Lights clean	Light fixtures clean	Mopping Floors clean	Gas stoves in good repair	Ovens, cookers in good repair
	Sig. (2-tailed)			0.006	0.161	0.176	-0.043	0.263	0.319	.399*	0.326	0.040	0.162	0.139
	N			0.978	0.443	0.390	0.865	0.160	0.287	0.032	0.079	0.833	0.448	0.537
Dishwashing machine- noise	Correlation Coefficient	10	8	25	25	26	18	30	13	29	30	30	24	22
	Sig. (2-tailed)	1.000	0.543	-0.115	-0.367	-0.367	0.115	-0.034	-1.000	-0.247	-0.568	-0.358	0.000	0.123
	N		0.130	0.769	0.297	0.297	0.854	0.921		0.464	0.068	0.279	1.000	0.736
Dishwashing machine producing heat	Correlation Coefficient	12	9	9	10	10	5	11	2	11	11	11	9	10
	Sig. (2-tailed)	0.543	1.000	0.658	-0.331	-0.331	-0.056	0.458	1.000	0.380	0.042	0.091	.907*	.856**
	N	0.130		0.108	0.468	0.468	0.944	0.254		0.353	0.920	0.830	0.013	0.007
Natural ventilation	Correlation Coefficient	9	9	7	7	7	4	8	2	8	8	8	6	8
	Sig. (2-tailed)	-0.115	0.658	1.000	0.097	0.306	-0.020	-0.010	0.466	0.251	0.074	0.159	0.354	0.339
	N	0.769	0.108		0.651	0.137	0.940	0.961	0.148	0.207	0.715	0.428	0.106	0.133
Adjusting Thermostatic Controls	Correlation Coefficient	9	7	27	24	25	16	27	11	27	27	27	22	21
	Sig. (2-tailed)	-0.367	-0.331	0.097	1.000	1.000**	0.353	0.304	0.553	0.057	0.059	0.224	0.061	0.026
	N	0.297	0.468	0.651			0.198	0.123	0.097	0.782	0.769	0.262	0.792	0.910
Adjusting Ventilating Equipment	Correlation Coefficient	10	7	24	27	27	15	27	10	26	27	27	21	21
	Sig. (2-tailed)	-0.367	-0.331	0.306	1.000**	1.000	0.410	.390*	.622*	-0.085	-0.038	0.292	0.201	0.026
	N	0.297	0.468	0.137			0.115	0.040	0.041	0.672	0.848	0.131	0.369	0.910
Adjusting Fans	Correlation Coefficient	10	7	25	27	28	16	28	11	27	28	28	22	21
	Sig. (2-tailed)	0.115	-0.056	-0.020	0.353	0.410	1.000	0.153	.698**	-0.223	-0.319	-0.377	-0.124	-0.470
	N	0.854	0.944	0.940	0.198	0.115		0.546	0.008	0.390	0.197	0.123	0.688	0.123
Air duct clean	Correlation Coefficient	5	4	16	15	16	18	18	13	17	18	18	13	12
	Sig. (2-tailed)	-0.034	0.458	-0.010	0.304	.390*	0.153	1.000	0.539	0.035	0.130	0.118	0.218	.427*
	N	0.921	0.254	0.961	0.123	0.040	0.546		0.057	0.850	0.479	0.521	0.296	0.038
Fans clean	Correlation Coefficient	11	8	27	27	28	18	32	13	31	32	32	25	24
	Sig. (2-tailed)	-1.000**	1.000**	0.466	0.553	.622*	.698**	0.539	1.000	0.462	0.224	0.272	0.150	-0.015
	N			0.148	0.097	0.041	0.008	0.057		0.131	0.462	0.368	0.660	0.973
Lights clean	Correlation Coefficient	2	2	11	10	11	13	13	13	12	13	13	11	8
	Sig. (2-tailed)	-0.247	0.380	0.251	0.057	-0.085	-0.223	0.035	0.462	1.000	.829**	.383*	.491*	.443*
	N	0.464	0.353	0.207	0.782	0.672	0.390	0.850	0.131		0.000	0.033	0.013	0.030

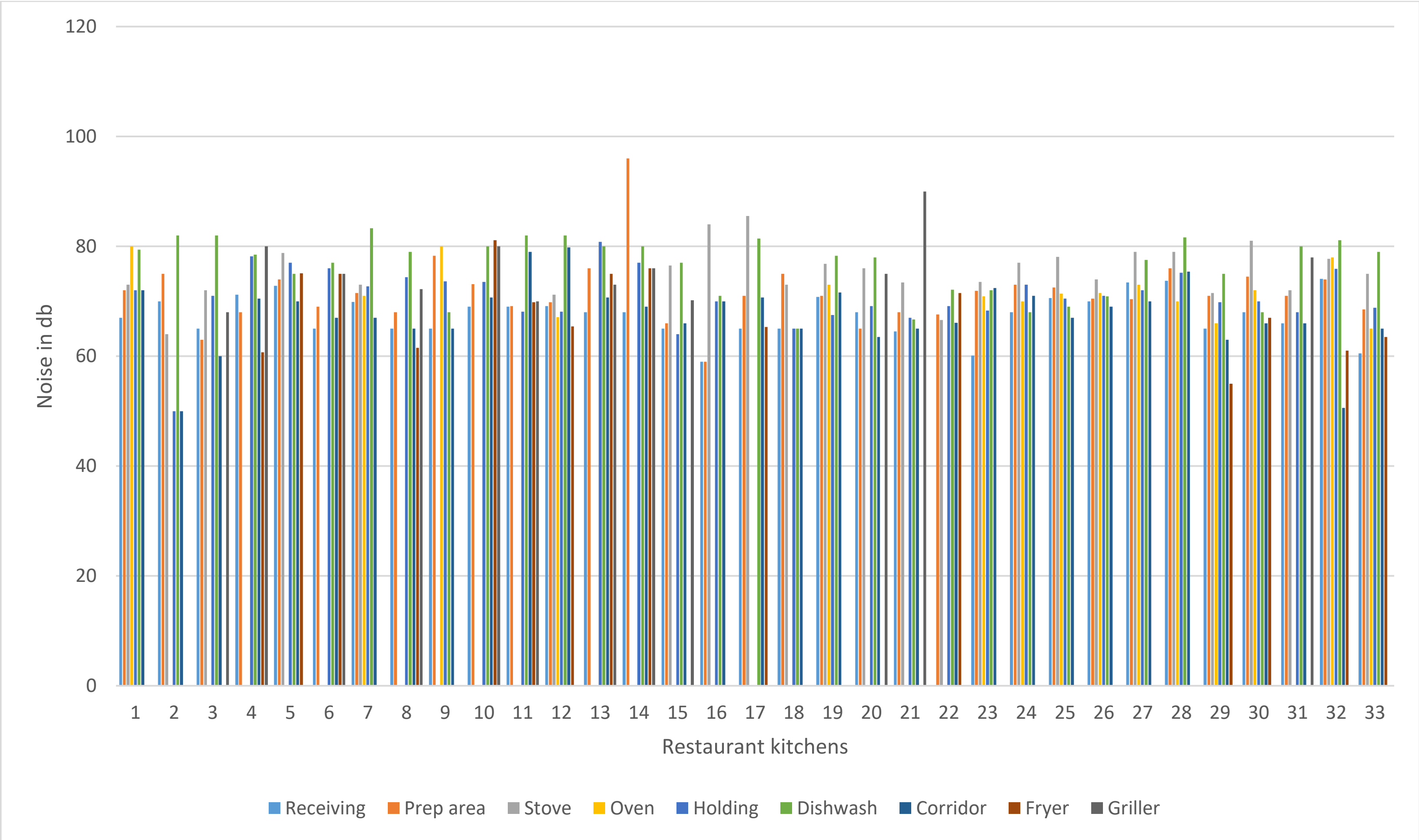
Light fixtures clean	Correlation Coefficient	11	8	27	26	27	17	31	12	31	31	31	25	24
	Sig. (2-tailed)	-0.568	0.042	0.074	0.059	-0.038	-0.319	0.130	0.224	.829**	1.000	0.347	.475*	0.307
	N	0.068	0.920	0.715	0.769	0.848	0.197	0.479	0.462	0.000		0.051	0.016	0.145
Mopping Floors clean	Correlation Coefficient	11	8	27	27	28	18	32	13	31	32	32	25	24
	Sig. (2-tailed)	-0.358	0.091	0.159	0.224	0.292	-0.377	0.118	0.272	.383*	0.347	1.000	0.318	.559**
	N	0.279	0.830	0.428	0.262	0.131	0.123	0.521	0.368	0.033	0.051		0.121	0.005
Gas cylinders stored away from kitchen	Correlation Coefficient	11	8	27	27	28	18	32	13	31	32	32	25	24
	Sig. (2-tailed)	-0.062		0.160	0.083	0.093	0.485	0.141		0.222	0.178	-0.249	0.210	
	N	0.865		0.456	0.708	0.665	0.079	0.476		0.255	0.364	0.201	0.314	
Gas stoves in good repair	Correlation Coefficient	10	7	24	23	24	14	28	12	28	28	28	25	21
	Sig. (2-tailed)	0.000	.907*	0.354	0.061	0.201	-0.124	0.218	0.150	.491*	.475*	0.318	1.000	.549*
	N	1.000	0.013	0.106	0.792	0.369	0.688	0.296	0.660	0.013	0.016	0.121		0.012
Ovens, cookers in good repair	Correlation Coefficient	9	6	22	21	22	13	25	11	25	25	25	25	20
	Sig. (2-tailed)	0.123	.856**	0.339	0.026	0.026	-0.470	.427*	-0.015	.443*	0.307	.559**	.549*	1.000
	N	0.736	0.007	0.133	0.910	0.910	0.123	0.038	0.973	0.030	0.145	0.005	0.012	
Any equipment producing too much soot	Correlation Coefficient	10	8	21	21	21	12	24	8	24	24	24	20	24
	Sig. (2-tailed)	0.050	0.500	0.009	-0.344	-0.344	-.704*	-0.265	-0.507	.516*	0.371	.535*	0.401	0.244
	N	0.916	0.391	0.972	0.162	0.162	0.023	0.272	0.199	0.028	0.118	0.018	0.139	0.363
	17	7	5	16	18	18	10	19	8	18	19	19	15	16

Appendix 26 Correlations between questionnaire with questionnaire

		Boilers and steamers	Fryers	HVAC & fans	All the kitchen equipment is in good repair	The amount of light in your kitchen is adequate	The staff are happy about adequate lighting in kitchen	The staff complain about glare (difficulty seeing in the presence of bright light such as direct or reflected sunlight) in the kitchen	Given the noise level can you talk to your colleague/neighbour in your kitchen without shouting	The staff complain frequently with regard to noise in the kitchen	The staff complain that they are unable to communicate with co-workers due to noise in the kitchen	The staff complained about blenders/grinders and/or food processor making too much noise	The staff complained about extractor making too much noise	The staff complained about humidity in the kitchen
Grinders and blenders	Correlation Coefficient	-.547*	-.491*											
	Sig. (2-tailed)	0.035	0.017											
	N	15	23											
Swivelling doors	Correlation Coefficient	-1.000**												
	Sig. (2-tailed)													
	N	2												
Air conditioner	Correlation Coefficient			-.894*										
	Sig. (2-tailed)			0.041										
	N			5										
The amount of light in your kitchen is adequate	Correlation Coefficient				.595**									
	Sig. (2-tailed)				0.000									
	N				34									
The staff are happy about adequate lighting in kitchen	Correlation Coefficient					.551**								
	Sig. (2-tailed)					0.001								
	N					34								

The staff complain about contrast (the difference in brightness or colour that makes an object clear) in kitchen	Correlation Coefficient					$-.480^{**}$	$-.480^{**}$	$.739^{**}$						
	Sig. (2-tailed)					0.004	0.004	0.000						
	N					34	34	34						
The staff complain that they are unable to communicate with co-workers due to noise in the kitchen	Correlation Coefficient								$-.649^{**}$	$.504^{**}$				
	Sig. (2-tailed)								0.000	0.002				
	N								34	34				
The staff complained about blenders/ grinders and/or food processor making too much noise	Correlation Coefficient								$-.465^{**}$	$.450^{**}$	$.742^{**}$			
	Sig. (2-tailed)								0.006	0.008	0.000			
	N								34	34	34			
The staff complained about extractor making too much noise	Correlation Coefficient									$.523^{**}$	$.431^{*}$	$.493^{**}$		
	Sig. (2-tailed)									0.002	0.011	0.003		
	N									34	34	34		
The staff complained about stoves and/or ovens making too much noise	Correlation Coefficient								-0.300	$.499^{**}$	$.523^{**}$	$.623^{**}$		
	Sig. (2-tailed)								0.084	0.003	0.002	0.000		
	N								34	34	34	34		
The staff complained about humidity in the kitchen	Correlation Coefficient												$.459^{**}$	
	Sig. (2-tailed)												0.006	
	N												34	
Staff complain about difficulty in breathing	Correlation Coefficient	$-.566^{**}$												$.561^{**}$
	Sig. (2-tailed)	0.009												0.001
	N	20												34
All kitchen equipment is installed as per specification	Correlation Coefficient				$.519^{**}$									
	Sig. (2-tailed)				0.002									
	N				34									$.682^{**}$
Staff complain that it is too hot in the kitchen	Correlation Coefficient													0.000
	Sig. (2-tailed)													34
	N													

Appendix 27 Mean Lighting levels of sampled kitchens



Appendix 28 Photographs of heat producing equipment in sampled kitchens

Wood Fired Pizza Oven

Gas fired Tunnel Pizza Oven

Electric and Gas restaurant cooking appliances

Tandoor and tandoor burner

Appendix 29 Turnitin Report

An exploration of Environmental Ergonomics; The case of restaurant kitchens in Durban

by Sasi Gangiah

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