Development of a sorghum and pearl millet-based instant breakfast cereal for the South African National School Nutrition Programme

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DECLARATION

I, Nqobile Ngcobo, hereby declare that the research work presented by this thesis is my original work and all the materials used are appropriately acknowledged and explicitly referenced. A reference list is attached to the thesis.

I also confirm that the thesis has not been submitted in any of its part or entirety for any degree in any other institution of higher learning internationally or locally.

I therefore give permission that my work be available for replication and/or for re-printing, for inter-library loan, and for the title and abstract of my mini dissertation to be made available to other educational institutions and students that might need it.

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DEDICATION

To those who believed in me, even when I did not believe in myself.

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Without the assistance and support of various important individuals, the research study and research report would not have been completed successfully. I would like to thank them from the bottom of my heart for everything:

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ABSTRACT

Background: The National School Nutrition Programme (NSNP) in South Africa was introduced in 1994 to address hunger, malnutrition, and access to food among disadvantaged school children. Many schools that access the NSNP are currently benefiting from sponsored breakfast programmes funded by major food companies; however, the initiative is provided to a limited number of schools. Despite these efforts, many learners start their day without breakfast, leading to low energy and poor concentration levels, highlighting a gap in the current NSNP meal provisioning structure. In 2024, the Department of Basic Education and National Treasury pledged to implement breakfast provisioning as part of the NSNP. However, the rollout has been delayed due to budget constraints and the limited range of breakfast options (maze-meal porridge) provided by major food companies. The revival of indigenous grains can contribute to achieving the Sustainable Development Goals (SDGs) focused on climate action, zero hunger, sustainable consumption, and good health and well-being. Developing a nutritious and filling breakfast porridge using indigenous grains could address hunger while providing learners with sustained energy and thereby enable them to focus until their next meal.

Aim: This study aimed to develop a tasty, nutritious, and cost-effective breakfast cereal suitable for the NSNP, using sorghum and pearl millet as the base ingredients.

Methodology: The study population consisted of learners aged 7-20 from four quintile 1-3 schools, two primary and two secondary schools, participating in the NSNP in the iLembe district of KwaZulu-Natal. A breakfast needs assessment, and preference survey informed the food product development process. Consent was obtained from 405 school learners to participate in the breakfast needs and preference survey. A sensory acceptable breakfast porridge was developed following the systematic steps of food product development using a 1:1 ratio of fermented sorghum and pearl millet. A pure lactic acid bacteria (LAB) starter culture was isolated and used to ferment the sorghum. To make the instant porridge, the fermented sorghum, pearl millet, and other ingredients were then cooked, dried, grounded and packaged.

The developed instant porridge underwent sensory analysis throughout the product development process using a 9-point hedonic rating scale. Consenting Food and Nutrition students experienced in the sensory assessment process were used to analyse the sensory acceptability of the trial recipes

during development. The instant porridge was also subjected to nutrient analysis, microbial, and shelf-life testing. Thereafter, the instant porridge underwent a final sensory analysis using a 7-point facial hedonic rating scale among 200 consenting learners aged 7-20 from the four participating schools to assess the product's sensory acceptability.

Results: The breakfast needs and preference survey showed that a significant percentage of the school learners most times consumed breakfast (35.1%) or sometimes consumed breakfast (49.9%) ($p<0.00$). It was found that most learners consumed breakfast inconsistently. Of the learners who inconsistently consumed breakfast, 56.7% indicated that they often skipped breakfast due to lack of time, whilst an alarming 30% said it was due to not having access to food. Primary school learners received a breakfast porridge from the NSNP at school, whereas high school learners did not. Popular breakfast cereals, such as Corn Flakes, All Bran Flakes and Weet-Bix, were preferred by 53.3% (n=216) among the learners. Regarding preference for breakfast porridge flavours, a significant percentage (40.2%) of the learners indicated that they preferred a chocolate-flavoured breakfast cereal ($p<0.001$).

The porridge had a protein content of 10.1g/100g, dietary fibre (5.8g/1100g), vitamin B1 (0.37mg/100g), B3 (16.46mg/100g), phosphorus (3.15mg/100g), iron (3.81mg/100g) and zinc (1.24mg/100g). The porridge was deemed microbiologically safe, and had a shelf-life of 12 months. Findings from the learner sensory assessment of the developed product by learners indicated that learners rated the product as 'good' (35.0%, n=70), 'super good' (26.5%, n=53) and 'really good' (14.5%=29). While both boys and girls rated the developed breakfast cereal above 4, on average, boys (mean = 4.7) rated it significantly higher than girls (mean = 4.16), ($p=0.002$, according to the t-test). However, there was no significant correlation between sensory scores across grade and age groups.

Conclusion: The findings of the current study highlights and emphasises the need to address the nutritional needs of NSNP learners by incorporating a breakfast component. The study identified the preferred quality attributes of the breakfast cereal by the quintile 1-3 school learners. A nutritious, cost-effective, fermented sorghum and pearl-millet porridge pocessing the preferred quality attributes was developed. The developed porridge can supplement the recommended daily allowance (RDA) shortfall of the NSNP and help achieve several SDGs for general health and

well-being. By offering a nutritious breakfast option, the developed porridge can improve school attendance and learners' cognitive performance, contributing to their overall growth and educational success. Sorghum and pearl millet, as indigenous grains, would play the role of an affordable, readily available key base ingredients and hence vital and sustainable source foods for improving the food and nutrition security of school learners accessing the NSNP.

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LIST OF ABBREVIATIONS

AOAC	Association of Official Analytical Chemists
DBE	Department of Basic Education
DEDEAT	Department of Economic Development, Environmental Affairs and Tourism
DPME	Department of Planning, Monitoring and Evaluation
DRI	Daily Reference Intake
DUT	Durban University of Technology
ECD	Early Childhood Development
FAO	Food and Agriculture Organization
HLPE-FSN	High Panel of Experts on Food Security and Nutrition
GCNF	Global Child Nutrition Foundation
GHP	Good Hygiene Practices
GHS	Global Household Survey
GMO	Genetically Modified Organism
HACCP	Hazard Analysis Critical Control Point
HGSMP	Home-Grown School Meals Programme
HLPE-FSN	High Panel of Experts on Food Security and Nutrition
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IOM	Institute of Medicine
IREC	Institutional Research Ethics Committee
IYM	International Year of Millets
KZN	KwaZulu-Natal
NGO	Non-Governmental Organization
NIDS-CRAM	National Income Dynamics Study-Coronavirus Rapid Mobile Survey
NSNP	National School Nutrition Programme
NY	New York
PNAE	Programa Nacional de Alimentação Escolar
PSNP	Primary School Nutrition Programme
RDA	Recommended Daily Allowance
RDI	Recommended Daily Intake

RTE	Ready-to-eat
SA	South Africa
SABS	South African Bureau of Standards
SANAS	South African National Accreditation System
SANHANNES	South African National Health and Nutrition Examination Survey
SDG	Sustainable Development Goal
SFP	School Feeding Programmes
SPSS	Statistical Package of Social Sciences
STATS SA	Statistics South Africa
UN	United Nations
UNICEF	United Nations Children's Emergency Fund
USA	United States of America
UNRWA	United Nations Relief and Works Agency
WBG	World Bank Group
WFP	World Food Programme
WHO	World Health Organization
WTO	World Trade Organization

CHAPTER 1: INTRODUCTION AND MOTIVATION FOR THE STUDY

1.1 Introduction

This chapter presents an overview of the research study. The following will be highlighted in this chapter: the importance of the study, the context of the research, the problem statement, the study's aim and objectives, the parameters and assumptions, the conceptual framework of the study, an outline of the study, key definitions, and the thesis structure.

1.2 Background and context

School feeding programmes are increasingly recognised as a crucial component of global efforts to improve educational outcomes and promote food security (Wang *et al.* 2021). They provide nutritious meals to children, especially in regions like Africa, where food insecurity and malnutrition are prevalent (Wineman *et al.* 2022). According to FAO *et al.* (2024) school feeding programmes play a vital role in providing a social safety net for children in need.

The Primary School Nutrition Programme (PSNP) was introduced in selected schools in 1994 as one of the food security intervention strategies of the South African government, and then it was renamed to the National School Nutrition Programme (NSNP) in 2004. It was intended to solve concerns about hunger and malnutrition, school enrolment and attendance, health, and access to food and education experienced by children from disadvantaged backgrounds (SA DBE and DPME 2016). However, according to the Constitution of the Republic of South Africa (*Constitution of the Republic of South Africa Ammendment Act* 1996), Section 27(1)(b), 'everyone has the right to have access to sufficient food and water'. Moreover, Section 27(2) indicates that "the state must take reasonable legislative and other measures within its available resources to achieve the progressive realisation of each of these rights'. Additionally, under Section 28(1)(c), the rights of children are spelt out as follows: every child has the right to 'basic nutrition, shelter, basic health care services, and social services'. Therefore, although the NSNP targets only disadvantaged children, the constitutional protection of human rights envisages that everyone has the right to food.

The NSNP was established with the aim to improve school attendance and enhance the learning capacity of learners through the provisioning of a healthy meal at 'no fee-paying' quintiles 1-3 schools, according to the South African public school quintile rankings (Ogbonnaya and Awuah

2019). The NSNP is regarded as one of the government's most effective intervention strategies to improve the food security conditions of historically disadvantaged children, especially vulnerable children in South Africa (DPME 2023).

The increasing levels of food insecurity exacerbated by the widespread and ongoing conflicts within and between countries, the effects of climate change, and economic slowdowns and downturns exacerbated by the COVID-19 pandemic have driven millions of people into extreme levels of hunger and malnutrition (World Food Programme 2022). The South African National Health and Nutrition Examination Survey (SANHANES)-1 (Shisana *et al.* 2014) reported that 33% of children between 10 and 14 years of age have no food in the house to eat for breakfast, and 29.8 % have nothing at home to put in their lunchbox to take to school. The world food crisis has been declared to be at unprecedented levels, the most serious in modern history, and as such, underlines the need for urgent action from governments, the private sector, civil society, and individuals (Crises *et al.* 2021).

As a result, the NSNP has proposed piloting a breakfast porridge or a snack at the start of the school day to supplement the mid-morning meal currently being served in the programme (DPME 2023). However, it is important to note that many schools are currently benefiting from sponsored breakfast programmes funded by major food companies in South Africa (Tiger Brands 2024). This is because the government does not have enough budget to cater for all learners (SA DBE 2024) . According to data from Stats SA, the South African government allocated R9.798 billion for the year 2024/25 to the NSNP. While these initiatives are designed to provide students with a nutritious start to the day, they often serve to promote the brands of these companies. Such marketing strategies can lead to the sale of products that may not necessarily align with healthy dietary guidelines. According to UNICEF's guidelines on the marketing of foods to children, these corporate influences may compromise the nutritional quality of the food children consume (WHO and UNICEF 2023).

Breakfast foods in the form of porridge are common and are made from different kinds of grain, such as maize, sorghum, and millet. According to Mabhaudhi *et al.* (2018), product development using indigenous foods that are well suited for the African climatic conditions, such as sorghum and millet, will contribute towards making the African food system sustainable and healthy under

increasing environmental change. Sorghum is rich in vitamins and minerals, and is an excellent source of energy due to its polysaccharide content (Amarakoon *et al.* 2021). Whole-grain sorghum, especially the red, brown, and black varieties, are rich in antioxidants (Awika and Rooney 2004). Millet is packed with fibre, protein, and antioxidants (FAO 2022). The high concentration of nutrients such as magnesium, zinc, iron, calcium, and B vitamins adds to the numerous health benefits of millet (Smart Foods 2020).

While rice, wheat, and maize hold the highest status as the major staple ingredients for porridge, sorghum and millet are equally important for the African food system because they have origins in the region (ICRISAT 2018). Interestingly, 2023 was declared as the International Year of Millets (IYM) by the United Nations General Assembly at its 75th session in March 2021 (FAO 2022). The IYM 2023 is an opportunity to raise awareness of the potential benefits of millets, from nutrition and health to environmental sustainability and economic development. The name 'millet' refers to a broad category of cereals that yield tiny grains or seeds from a naturally varied group of grass species (FAO 2023). Millets are among the world's oldest and most adaptable foods, and they are a staple of many traditional and indigenous culinary traditions. They are also referred to as 'coarse', 'small', or 'minor' grains in various regions of the world (FAO 2023). According to Singh *et al.* (2014) millets may be divided into two categories: major millets, such as sorghum, pearl millet, and finger millet, and minor millets, such as foxtail millet, kodo, barnyard millet, little millet, and proso millet.

The IYM 2023 was proposed to strengthen the interaction between science and policy, facilitate partnerships, mobilise stakeholders to produce and promote millets, and encourage the consumption of millets by the general public. The IYM 2023 aims to promote research and development into the sustainable and resilient production of millets, while highlighting millets' potential to provide new market opportunities for farmers and producers, and innovative products for consumers (Mishra *et al.* 2023).

In addition, the resurgence of indigenous grains is essential to achieving the Sustainable Development Goals (SDGs) in particular, SDG 13 (Climate action), SDG 2 (Zero hunger), SDG 12 (Sustainable consumption and production), and SDG 3 (Good health and well-being), according to the (FAO 2022). Thus, the goal of this study is to develop a sorghum and millet instant porridge

for the NSNP to enhance the learning capacity of learners while providing a nutritious alternative to the current breakfast porridge offering.

1.3 Problem statement

Currently, the NSNP is not able to cover the RDA, falling short by as much as 7% of the Recommended Daily Allowance (RDA), requirement for the target group (SA DBE and DPME 2016). The major contributing factor leading to this shortfall in meeting the RDA is the budget required to improve the current NSNP meals (SA DBE and DPME 2016). As a result, learners are only provided with one meal mid-morning after having no access to any substantial nutrition to help them focus on the (early) morning lessons to improve their overall learning experience. A proposed approach to increasing the effectiveness and impact of the NSNP on the nutrition challenge is the provision of two nutritious meals, preferably one in the morning as a breakfast meal before classes commence, and another one later in the day as lunch.

By providing an additional meal, preferably a breakfast option, the South African government has an opportunity to improve the overall nutrition of learners through the school feeding programme (SA DBE and DPME 2016). The development of a cost-effective, sensory-acceptable, and nutrient-dense breakfast porridge can fill would go a long way in supplementing 18.0% of the children's RDA, which is currently provided by the NSNP (DPME 2023, SA DBE and DPME 2016). Embracing the use of culturally acceptable ancient grains such as sorghum and pearl millet in the development of ready-to-eat (RTE), convenient breakfast porridge will enhance the nutritional value of school breakfast, and promote food diversity and sustainability while addressing food security challenges.

1.4 Aim of the study

This study aims to develop a tasty, nutritious, and cost-effective breakfast porridge that can be included as a breakfast option in the NSNP. The breakfast option will supplement the gap in the RDA shortfall that the current NSNP cannot cover.

1.5 Objectives

- To conduct a needs and preference assessment for breakfast provisioning for learners by conducting a breakfast needs assessment and preference survey.

- To develop a nutritious and cost-effective breakfast cereal using the steps of product development and to determine the nutrient content of the breakfast cereal through nutritional analysis.
- To determine the microbiological level and shelf-life stability of the breakfast cereal through microbiological tests and shelf-life analysis.
- To conduct a sensory evaluation survey to establish the acceptability and palatability of the breakfast cereal among learners in the NSNP.

1.6 Study parameters

- The study was limited to the iLembe district in KwaZulu-Natal (KZN) province.
- Only two primary and two high schools within the NSNP were used for this study.
- Red sorghum was the only variety of sorghum used in this study.
- Pearl millet was the only variety of millet used in this study.
- The breakfast porridge was developed at the Durban University of Technology (DUT), Department of Consumer Science: Food and Nutrition Masters Laboratory.
- The sensory assessment throughout the product development process of the food product was limited to young adults (n=8) attending DUT, Berea Campus, South Africa.
- The needs assessment and preference survey, and sensory assessment of the breakfast porridge were completed by learners aged 7-20 years at four selected schools in the iLembe district, South Africa.
- For the needs assessment and preference survey, 415 participants were used, 10 for the pilot and 405 for the final instrument.
- For the final sensory assessment, 210 participants were used, 10 for the pilot and 200 for the final sensory assessment.
- The sorghum and millet breakfast porridge were analysed for various minerals and B vitamins based on the current national micronutrient deficiencies.
- Each learner received one 50g sample of the breakfast porridge for sensory assessment.

1.7 Assumptions

- It was assumed that all learners attending the four schools were part of the NSNP.
- It was assumed that learners attending the four schools do not bring a lunch pack.

- It was assumed that the responses and data collected from school learners for the needs assessment and preference survey, and sensory assessment are of an unbiased and honest nature.
- It is assumed that all learners involved in the research can comprehend English, which was the language used to communicate, and where required, a translated needs assessment and preference survey and sensory assessment sheet were given to learners who preferred to communicate in isiZulu.

1.8 Conceptual framework

The research was conducted according to the conceptual framework shown in Figure 1.1, which also outlines the goals of the investigation and the overview of the research activities in Figure 1.2. The first research objective acted as a foundation for the study, aiding significantly in understanding the breakfast requirements and choices of school learners. This understanding informed the development of a breakfast porridge suitable for the NSNP. Thereafter, the nutritional composition, microbial safety and shelf-life of the breakfast porridge were assessed. Additionally, the sensory acceptability of breakfast porridge was investigated among school learners. In this context, the above framework shows the holistic view of the development of a nutritious, cost-effective and sensory-acceptable porridge using sorghum and pearl millet.

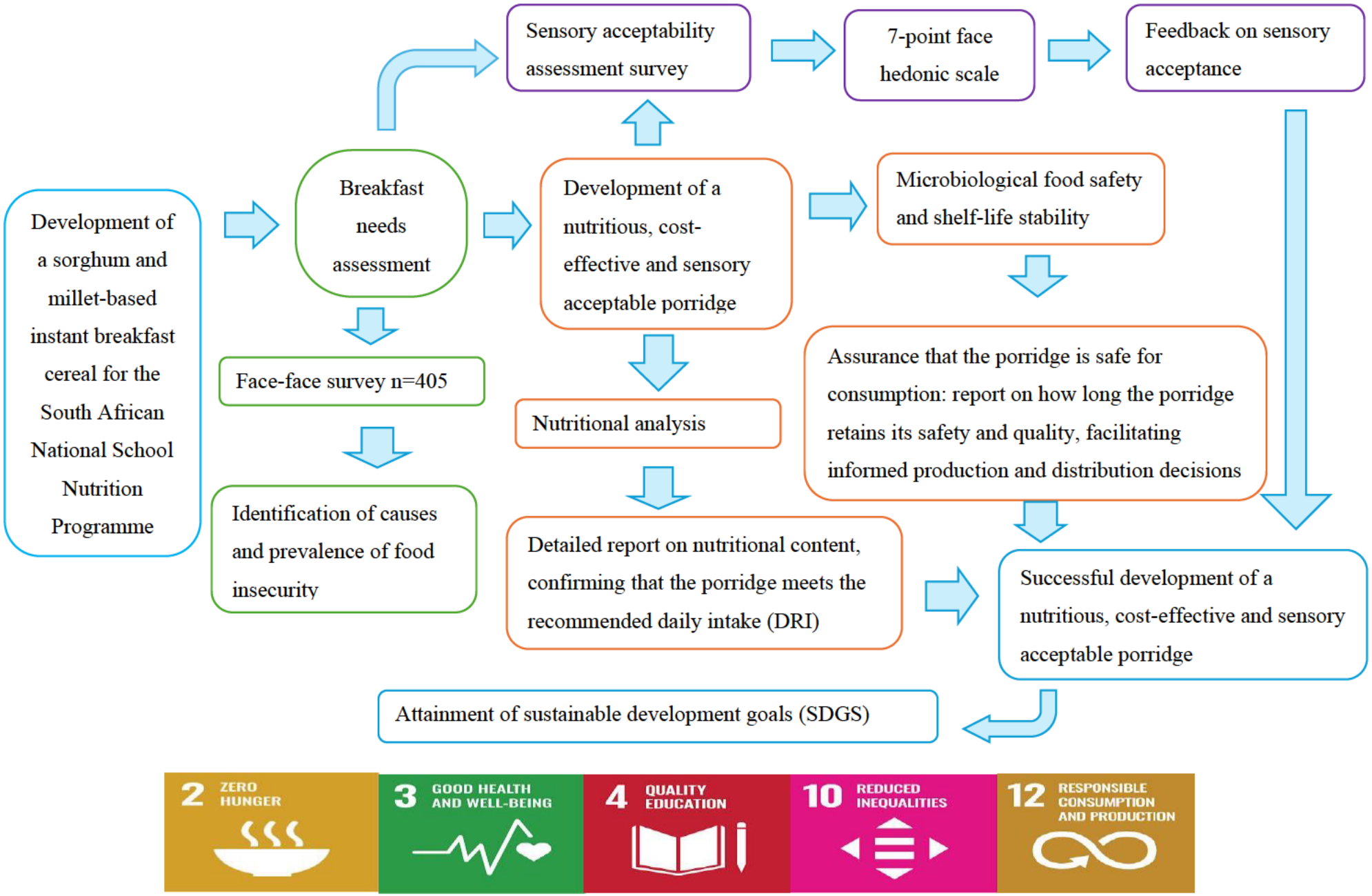


Figure 1. 1: Conceptual framework of the research methodology

1.9 Outline of the project

The outline of the study, as depicted in Figure 1.2, was developed together with the research supervisors.

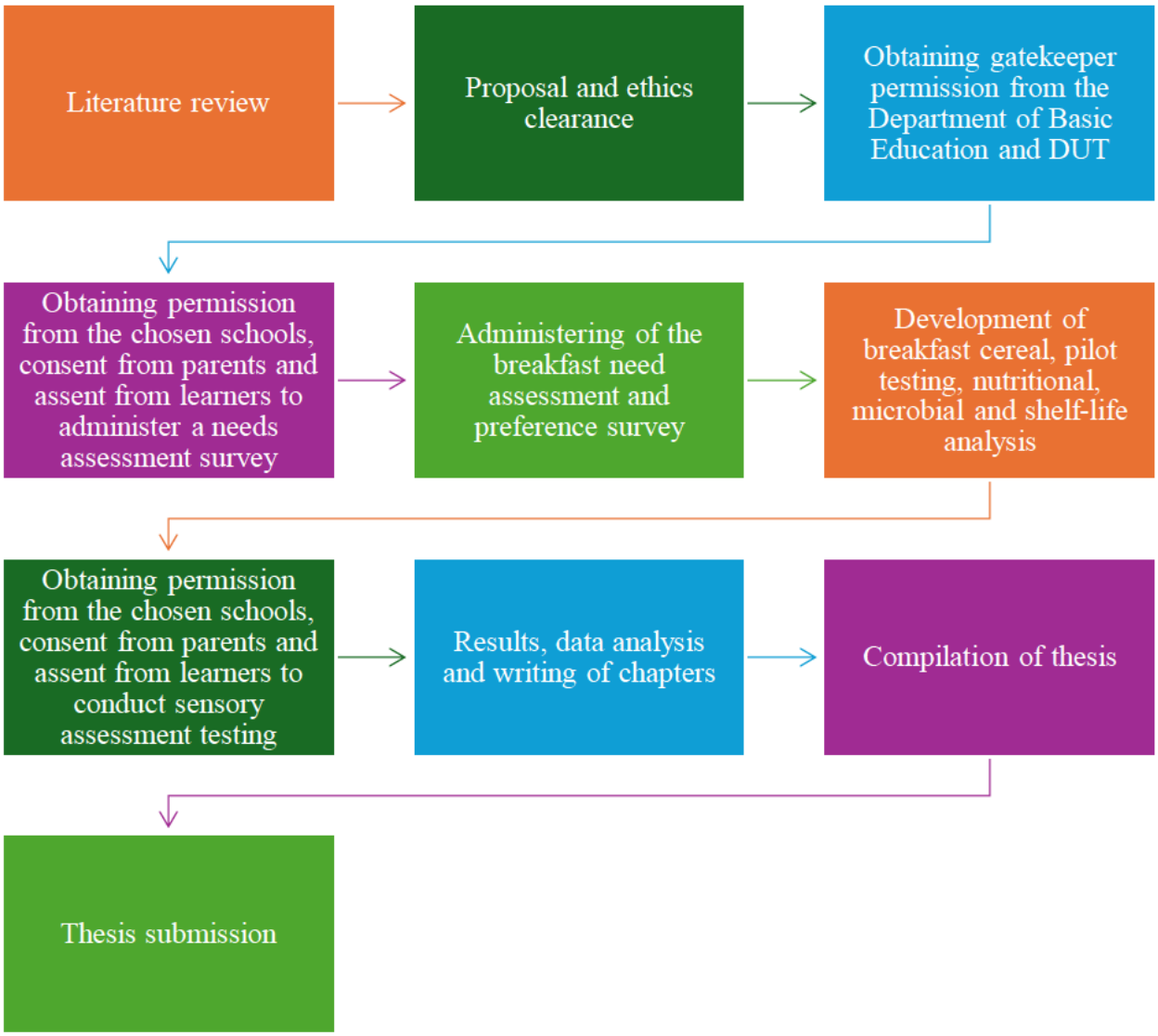


Figure 1. 2: Outline of the study

1.10 Definition of terms

Product development: Research activities on a product's raw materials, quality control, packaging, production, nutritional value labelling, technology, and marketing, aiming to bring a product from concept to market release (Earle and Earle 2007; Joseph and Sharman 2022).

National School Nutrition Programme: Was established in South Africa to ensure that hunger will not be a barrier to learning among school learners attending quintile one to three schools and aims to provide a free, nutritious meal for all 189 school days (SA DBE and DPME 2016).

Quintile: Schools in South Africa are ranked according to fees, where quintiles one to three are 'no-fee paying schools', and quintiles four and five are 'fee-paying schools' (South African Department of Basic Education 2020).

Recommended Dietary Allowance (RDA): Average daily level of intake to meet the nutrient requirements of almost all healthy people (National Institute of Health 1995).

Food security: 'Exists when all people at all times have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life' (FAO 2000).

Nutrition security: 'A person is considered nutrition-secure when she or he has a nutritionally adequate diet, and the food consumed is biologically utilized such that adequate performance is maintained in growth, resisting or recovering from disease, pregnancy, lactation, and physical work' (FAO 2009).

Malnutrition: 'Deficiencies, excesses, or imbalances in a person's intake of energy and/or nutrients" (WHO 2024).

Stunting: Low height-for-age. Chronic undernutrition resulting from poor socioeconomic conditions, poor maternal health, frequent illness, and inappropriate early childhood care hinders children's physical and cognitive potential (WHO 2024).

Wasting: Low weight-for-height. A condition characterised by severe underweight due to insufficient food or diseases (WHO 2024).

Obesity: Abnormal, or excessive fat accumulation. A BMI $\geq$ 30 kg/m^2 is defined as obese (WHO 2021).

Overweight: Abnormal, or excessive fat accumulation that may impair health. The prevalence of overweight is assessed using body mass index, and defined as weight in kilograms divided by the square of the height in metres $kg/m^2 \geq 25\ kg/m^2$ (World Health Organization 2021).

Antioxidants: Substances that protect cells against damage caused by free radicals and can reduce oxidative stress and minimise the risk of numerous chronic diseases (Grosso *et al.* 2017).

Flavonoids: A group of natural substances with variable phenolic structures as found in fruits, vegetables, grains, bark, roots, stems, flowers, tea, and wine (Panche, Diwan and Chandra 2016).

Phenols: Compounds containing hydroxylated aromatic rings; the hydroxy group is attached directly to the phenyl, substituted phenyl, or another aryl group (Swanson 2003).

Sustainability: 'Meeting the needs of the present generation without compromising the ability of future generations to meet their own needs' (Brundtland and Mansour 2010).

Zero-rated: Products that are exempt from Value Added Tax (Majaski 2021).

Sensory assessment: A rating system used to identify different attributes of a product through the five senses: taste, sight, smell, hearing, and touch (Carpenter, Lyon and Hasdell 2000).

1.11 Structure of the thesis

This thesis is reported according to the following format:

Chapter 1: Introduction and motivation for the study

Provides the background to the study, research problem, and motivation of the research. The aim and objectives of the research are also presented.

Chapter 2: Literature Review

This chapter presents and reviews literature related to the research topic and relevant information about the study.

Chapter 3: Methodology

The research design, methods, and tools used to carry out the study, including ethical considerations, fieldwork protocol, and data analysis, will be discussed in this chapter. Also included is the study's validity and reliability.

Chapter 4: Results and Discussion

This chapter presents a compilation of the data collected and correlations drawn, with a discussion of the outcomes relative to the reviewed literature.

Chapter 5: Conclusion and Recommendations

Limitations to the study and suggestions for future research are included here, along with the conclusions of the research study.

1.12 Conclusion

Chapter 1 has outlined the purpose and importance of the study. A framework (Figure 1.1) and structure is also included in this chapter as a guide to the development of the research. In the next chapter, the literature pertaining to the study is reviewed.

1.13 Referencing style

The referencing style used in this thesis is according to the guidelines used by DUT; DUT Harvard reference style on Endnote.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

This literature review sets the foundation for the current study by summarising existing research, identifying gaps, and positioning the investigation within the wider academic context. This chapter aims to present a comprehensive literature review exploring the relationship between food security and nutrition security, clarifying the distinction, and identifying contributing factors to food and nutrition insecurity. The objective is to deepen the understanding of the complex systems influencing population health outcomes. The chapter presents a global overview of food and nutrition security, with a particular focus on South Africa. This section highlights the current challenges related to food and nutrition insecurity and ways of improving household food security within the country. Special attention is paid to the historical background of school feeding programmes in this regard as the essential tool for addressing the issues of a nutritional deficit.

Furthermore, the review also compares the NSNP in South Africa with other school feeding initiatives in different countries. It also provides a summary of the financial costs associated with these nutrition interventions based on the primary foods offered in school feeding programmes worldwide and best practices in models that have been adopted. Additionally, this chapter delves into the nutritional and health potential of sorghum and pearl millet, discussing their classification, nutritional profiles, and applications in food systems. The impact of fermentation on sorghum is discussed in detail, emphasising its role in enhancing nutritional value and food quality. The chapter further outlines the key steps in food product development, underscoring the importance of sensory analysis as a vital component of creating new food products. These interconnected topics are discussed to establish a foundation for developing an instant breakfast cereal with sorghum and pearl millet suitable for the NSNP.

2.2 Food and nutrition security

2.2.1 The difference between food security and nutrition security

“Food security exists when all people at all times have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life” (FAO 1966). However, according to the International Food Policy Research Institute (IFPRI), nutrition security is defined as having “adequate nutritional status in terms of protein, energy, vitamins, and minerals for all household members at all times”(Quisumbing *et al.* 1995).

Nutrition security emphasises the quality and nutrient density of food, indicating that access to food is necessary and that food must also be nutritionally adequate (FAO, IFAD and WFP 2012). “Nutrition security refers to the need to secure access to an appropriately nutritious diet, comprising all essential nutrients and water, coupled with a sanitary environment and adequate health services and care to ensure a healthy and active life for all household members” (FAO, IFAD and WFP 2012). This highlights the interplay between food access, nutritional quality, and overall health, suggesting that food security is a foundational component of nutrition security.

Siassi (2015) emphasises this connection between food security and nutrition security by stating that “nutrition security exists when all people at all times consume food of sufficient quantity and quality in terms of variety, diversity, nutrient content and safety to meet their dietary needs and food preferences for an active and healthy life, coupled with a sanitary environment, adequate health, education and care.” This focus on quality underscores how gaps in food security can adversely affect nutritional outcomes.

Furthermore, Siassi (2015) and the SA DAFF (2013) concur that food security and nutrition security are closely related and complement one another to realise the objective of a healthy society. For instance, a household experiencing food insecurity may have a diet with enough calories to survive, but it may lack essential vitamins and minerals, leading to undernutrition (Hamsa *et al.* 2023). Conversely, improving access to a diverse range of foods is likely to enhance nutritional outcomes (UNICEF 2021), showcasing the mutual reinforcement of these concepts. Creating comprehensive policies to enhance population health requires an awareness of the complex link between food security and nutrition security.

2.2.2 The pillars of food security

According to the Committee on World Food Security (2012), Ericksen (2008), FAO (2008), Timmer (2012), and the United Nations System High Level Task Force on Global Food Security (2011), the state of food insecurity revolves around availability, accessibility, stability and utilisation of food. El Bilali *et al.* (2019a) describes the term "availability" as the consistent availability of sufficient amounts of food. The amount of food that is produced, net trade, and stock levels all affect food availability.

According to El Bilali *et al.* (2019a), the term "access" describes having enough money to buy the right food for a healthy diet. Economic access (i.e., the ability to purchase food), physical access (i.e., transportation and infrastructure), and sociocultural access and preferences are all related to accessibility (El Bilali *et al.* 2019a). More attention must be paid to food prices, earnings, expenses, and markets to allow food access. The suitable usage based on food safety, social value, and nutritional value is “the

utilisation" factor. Feeding habits, food preparation, diet variety, and equitable intra-household food distribution contribute to utilisation. Utilisation is defined as the suitable usage based on food safety, social value, and nutritional value (El Bilali *et al.* 2019a).

The phrase "stability" refers to the ability to resist disasters and shocks that affect long-term food security, such as political unrest, unfavourable weather, or economic issues. According to Berry *et al.* (2015), all four interconnected and interdependent pillars are necessary for food security. Food insecurity occurs when the four pillars are not fulfilled (El Bilali *et al.* 2019b). The food system experiences either short-term, transitory, or long-term chronic food insecurity if any one of the four pillars is not fulfilled (El Bilali *et al.* 2019a). The FAO, WBG and WTO (2023), define transitory food insecurity as "a short-term or temporary inability to meet food consumption requirements related to sporadic crises, indicating a capacity to recover". In contrast, the FAO defines chronic food insecurity as "food insecurity that persists over time, largely due to structural causes" (FAO *et al.* 2024).

Food insecurity in impoverished areas of sub-Saharan Africa is also significantly influenced by food availability (FAO *et al.* 2024). According to the FAO (2017) and FAO, IFAD, and WFP (2014), utilisation is still an issue, particularly for emerging nations like those in Eastern Asia and Latin America. At the same time, issues such as the absence of nutrition policies for infants and young children, inadequate access to a safe and clean water supply, inadequate sanitation facilities, and health care, as well as unfavourable effects resulting from the food environment and its culture, are additional variables that contribute to food and nutrition insecurity.

Clapp *et al.* (2022a) advocated for the official acknowledgement of agency and sustainability as crucial pillars of food security that were initially proposed by the High Level Panel of Experts on Food Security and Nutrition (HLPE) in their 2020 report, "Food Security and Nutrition: Building a Global Narrative Towards 2030." Today it is widely believed that addressing the growing disparities in food systems, such as power imbalances among actors, requires agency, which is defined as the ability of individuals and groups to exert some control over their circumstances and to participate in governance processes meaningfully (Clapp *et al.* 2022b). Sustainability refers to "food system practices that contribute to long-term regeneration of natural, social, and economic systems, ensuring the food needs of the present generations are met without compromising the food needs of future generations" (HLPE-FSN. 2020). Everyone on earth will have improved access to food security, not just now but also in the future, if agency and sustainability are incorporated into frameworks for food security policy and analysis (Clapp *et al.* 2022a).

2.2.3 Status of global food and nutrition security

Conflict, climatic extremes, economic shocks, and rising inequality are just a few of the many variables that impact the state of food and nutrition security worldwide (FAO *et al.* 2022). World hunger and extreme food insecurity have increased due to the COVID-19 pandemic, which brought to light the weaknesses in our agrifood systems and revealed social injustices. In addition, economic impacts, including the Russian invasion of Ukraine, have driven food prices to record highs, leaving people in low and middle-income countries particularly vulnerable (Wudil *et al.* 2022).

The number of incidences of undernourishment increased from 8.0 to 9.3% between 2019 and 2020 and then more slowly to 9.8% in 2021 (FAO *et al.* 2022). Three years later, the global incidence of undernourishment was placed at 9.1%, with 20.4% of the affected population in Africa, in contrast to 8.1% in Asia, 6.2 % in Latin America and the Caribbean, and 7.3% in Oceania. According to updated forecasts by the FAO which highlighted the enormous difficulty of achieving SDG 2 (Zero Hunger), an estimated 582 million people are predicted to still experience chronic undernourishment by 2030 (FAO *et al.* 2022). Compared to a scenario based on the world economy before the COVID-19 pandemic, the estimate indicates an increase of almost 130 million undernourished people between 2019 and 2030 (FAO *et al.* 2024).

Although progress has been made in reducing stunting among children under 5 years, as evidenced by a decrease from 33.1% (201.6 million) in 2000 to 22.0% (149.2 million) in 2020 (FAO *et al.* 2022), it remains a major challenge along with other forms of malnutrition, such as, wasting, and obesity. In 2020, 45.4 million children under five displayed wasting, which was 6.7% of the total population. However, the number of obese individuals is still increasing; according to WHO (2022), there are already over 1 billion obese people globally, including 650 million adults, 340 million adolescents, and 39 million children. According to predictions made by the WHO, 167 million adults and children will be unhealthy by 2025 as a result of being overweight or obese (WHO 2022).

2.2.4 The state of food and nutrition security in South Africa

Despite South Africa's national food security status, various problems have made it extremely difficult for many people to obtain food. This has resulted from rising energy prices, high rates of unemployment and poverty, growing interest rates, and a protracted energy crisis (Adeniyi, Losch and Adelle 2021). Furthermore, eating has become less affordable for many individuals due to the growing cost of living,

which includes ever-increasing food and fuel prices. Consequently, there is a higher chance that people and households may go hungry and experience food insecurity (Stats SA 2023).

According to a study conducted in 2017, the provinces with the lowest percentage of families with sufficient food availability were the North West (64.0%) and Northern Cape (66.5%) (Stats SA 2019). Furthermore, Stats SA (2019) showed a notable difference in food availability across the demographic groups studied. Specifically, Black and coloured households were less likely to have sufficient access to food than those headed by Indians and Whites (Stats SA 2019). In contrast, results from a study conducted in 2021 (Dlamini *et al.* 2023a) showed that while food insecurity varied significantly across various provinces, over 20% of South African families had insufficient access to food. In particular, the Eastern Cape had the highest percentage of inadequate food access (31.7%), while the Northern Cape had the lowest rate (5.7%).

Furthermore, households in rural (21.3%) and pre-urban (21.5%) regions experienced higher levels of food insecurity (17.5%) than their urban counterparts (Dlamini *et al.* 2023a). Moreover, food insecurity rates among Coloured (24.2%) and Black (22.6%) South Africans were much higher than those among whites (4.9%) and Asians (3.7%), highlighting the socioeconomic divide.

Additionally, Dlamini *et al.* (2023a) report a noteworthy relationship between food security and educational achievement in South African families, with 45.7% of those without a formal education having inadequate access to food. Interestingly, unemployment was also a major contributing factor to food insecurity; of the respondents, 36.5% were jobless, and 13.5% were employed (Dlamini *et al.* 2023a). A Stats SA (2023) analysis found that 7.9% of families with at least one employed person faced hunger, compared to approximately 19.0% of those without an employed member. These results confirm that socioeconomic status significantly impacts food availability in South Africa.

Based on data from the South African General Household Survey (GHS) (2019) conducted before the national survey (before the COVID-19 pandemic), 7% of the population was severely food insecure, and 17.3% was moderately or severely food insecure (Stats SA 2019). Even though self-reported hunger has significantly reduced over time, the COVID-19 pandemic has led to a gradual return to pre-pandemic levels in household and child hunger (Van der Berg, Patel and Bridgman 2022). According to the National Income Dynamics Study-Coronavirus Rapid Mobile Survey (NIDS-CRAM survey), 18% of South African families in 2020 suffered from moderate to severe hunger (Van der Berg, Patel and Bridgman 2022).

According to a more recent Stats SA (2019) report, in 2021, nearly 80% (14.2 million) of South African households reported having adequate access to food, while 15% (2.6 million) and 6% (1.1 million) reported having inadequate and severely inadequate access, respectively. Nearly half a million of these families were located in the two biggest cities, Johannesburg (238 610) and Cape Town (240 970), with two-thirds of them living in urban areas (Stats SA 2023).

In 2021, over half a million (683 221) households with children aged five and younger reported hunger (Stats SA 2023). Children who do not receive sufficient nutritious food cannot develop sufficiently and are at significant risk of acute malnutrition, which can result in stunting and has an impact on both physical and cognitive development in malnourished children (UNICEF 2013). Of the households with children five years and younger reported to be hungry, 20.4% were in KZN, 22.2% in Gauteng, and 14.5% in the Western Cape (Stats SA 2023). Children who are malnourished and hungry struggle to concentrate and learn, making them susceptible to repeating the cycle of poverty and illness (UNICEF 2019).

2.2.5 Strategies to increase household food security

Ending world hunger and improving food security are leading challenges that must be prioritised by all heads of state globally (FAO, IFAD and WFP 2014). Effective strategies to enhance food security include promoting local food production, which minimises disruptions caused by globalisation and international uncertainties (HLPE-FSN. 2020). Encouraging urban and rural households to engage in agricultural activities can empower them to produce their own food and diversify farming practices to include resilient crops and livestock suitable for challenging climatic conditions (Ngcamu, Chari and Health 2020; Stats SA 2023).

In 2015, the United Nations adopted 17 Sustainable Development Goals (SDGs), committed to address various issues and improve quality of life for all people (UN 2020). Poverty, inequality, climate change, environmental degradation, peace, and justice are among the global issues addressed by the SDGs. Goal 2 strives to eliminate hunger and guarantee that everyone can have access to safe, nutritious food, while Goal 3 promotes improved health and well-being. These goals are interconnected, emphasising that food security can improve health outcomes and contribute to societal prosperity. By aligning initiatives with the SDGs, governments and organisations can create a framework for sustainable development that addresses the root causes of hunger and promotes inclusive growth.

The South African government provides a support allowance to low-income parents of children under the age of 18 to combat hunger and food insecurity (Granlund and Hochfeld 2020). In 2023, the child support grant was increased from R480 to R510. Furthermore, various government programmes exist to combat food insecurity in South Africa, including food fortification, food supplementation, and school feeding programmes such as the NSNP as well as daycare centre schemes (Labadarios *et al.* 2011a). Furthermore, various government programmes exist to combat food insecurity in South Africa, including food fortification, food supplementation, and school feeding programmes such as the NSNP and daycare centre schemes (Labadarios *et al.* 2011b).

However, a review of food and nutrition policies from 2002-2018 indicated that many initiatives lacked input from relevant stakeholders, undermining their effectiveness (Kushitor *et al.* 2022). Therefore, policies that address food and nutrition security need to take a multifaceted approach and prioritise stakeholder engagement to avoid duplication and ensure clarity, as joint efforts are necessary to develop pathways that will sustainably improve family food security (Boatemma, Drimie and Pereira 2018). Therefore, policies addressing food and nutrition security must take on a multifaceted approach.

2.3 School feeding programmes

2.3.1 The history of school feeding

The history of school feeding programmes dates back to the 18th century. In schools in Munich, Germany, a programme that fed hungry children was launched in 1790 (Bosselman 1982). The feeding programme offered daily wholesome and cost-effective meals to address food insecurity among children and their families. The provision of meals improved school attendance and participation, encouraging reading and education at a time when child labour was still common. The programme included whole families and helped eradicate poverty by feeding those who were struggling financially. The initiative sought to address unemployment and vagrancy by supplying food and education, promoting social stability (Bosselman 1982). Similar programmes were inspired by the Munich school feeding programme's success, proving that these kinds of programmes could combat hunger and advance education more broadly (Berg and Muscat 1973).

In France, a school lunch programme for underprivileged children was established in around 464 districts in 1867. The school lunch programme served a soup of barley, peas, and potatoes every day (Bosselman 1982).

Private funding was used for most of the early feeding initiatives (Berg and Muscat 1973); for example, a Buddhist priest-initiated school feeding programme in Japan in 1889 was funded with alms. In 1900, the government of the Netherlands became the first nation to recognise the need for and make meals available at schools (Berg and Muscat 1973).. Three years after the legalisation of the feeding programme in the Netherlands, the Danish and Swiss governments followed, making the programmes compulsory in government schools (Berg and Muscat 1973). However, it was not until 1932, amidst economic depression, that a nationally funded programme was launched and school feeding programmes were extended (Berg and Muscat 1973). In 1900, in the first national legal recognition of a government's responsibility, the Netherlands authorised local governments to make meals available at school for youngsters to improve children's physical development and regular attendance" (Richter, Griesel and Rose 2000). Within three years, Denmark had legalised similar programmes, and Switzerland had made them compulsory (Berg and Muscat 1973).

Despite these developments, not all countries were receptive to institutionalised public feeding programmes. Belgium objected to the concept of free school feeding because they believed it intruded on the parents' role (Berg and Muscat 1973). Finland permitted school lunch programmes; however, to avoid any sense of dependence, it was stipulated that school gardens must be established to support them (Berg and Muscat 1973). Brazil also had early programmes. However, mass distribution only began in the early 1960s. Although early programmes differed, they were generally on a small scale, sponsored by private charitable groups, explicitly directed at poorer children, and often concerned only with milk distribution (Berg and Muscat 1973). Governments started sponsoring these programmes as they developed, offering a wider variety of foods to children from all socioeconomic backgrounds.

To address widespread poverty and hunger during the Great Depression in the 1930s, school feeding programmes were extended in the US to improve children's physical development Richter, Griesel and Rose 2000). School feeding programmes later expanded to other countries outside the UK and the US. The mid-20th century saw several countries adapting elements of these programmes to address local needs (Berg and Muscat 1973). For instance, during and after the First World War, several affluent countries expanded their programmes to help feed the needy abroad in the distress brought on by the Second World War (Berg and Muscat 1973). Their efforts were channelled through the United Nations Relief and Works Agency (UNRWA), the United Nations Children's Fund (UNICEF), and the World Food Program of the Food and Agriculture Organization (FAO) (Berg and Muscat 1973).

According to Tomlinson (2007), South Africa started its school feeding programme in the early 1940s, providing free milk to children at White and Coloured schools. Today, the broader breadth of school food programmes include full meals, vitamin supplements, or fortified biscuits (Adams *et al.* 2017). In the US and the UK, these meals are often provided at full or reduced cost; in underdeveloped countries, they are typically provided for free. However, many of the feeding programmes have dubious nutritional value and quality (Tomlinson 2007). These programmes focused more on providing sufficient calories rather than ensuring a balanced diet with adequate vitamins, minerals, and other essential nutrients (Tomlinson 2007).

Over the years, school feeding programmes in developing countries have increased in popularity (Hassanally, Naicker and Singh 2020). According to Hassanally, Naicker and Singh (2020), school feeding programmes are today still a crucial instrument for enhancing learners' education and nutrition. The FAO (2019b) asserted that school lunch programmes have emerged as a significant factor in improving nutrition and promoting sustainable development. School feeding programmes have become increasingly popular in developing countries (Hassanally, Naicker and Singh 2020).

2.3.2 School feeding programmes globally

School feeding programmes are implemented in many countries worldwide, with varying approaches and objectives (Buhl 2010). Domestic and international donor funding is important in lower- and middle-income nations (WFP 2024). Brazil's National School Feeding Programme (Programa Nacional de Alimentação Escolar; PNAE), which was started in 1955, is the world's biggest and longest-running school feeding programme in the world (Kitaoka 2018). The PNAE serves an estimated 42.6 million learners in public schools to contribute to growth, biopsychosocial development, learning, academic achievement, and healthy eating habits throughout the school year (Kitaoka 2018).

The successful legislation of the school feeding programme in the Netherlands led to the adoption of the goal of reducing extreme hunger among children to promote enrolment and facilitate learning (Berg and Muscat 1973). Denmark legalised a similar programme three years after the Netherlands' school feeding programme legislation was successfully passed, and the Swiss government also made them compulsory (Berg and Muscat 1973). Children in basic and upper primary schools attending government and government-aided schools in India are entitled to free meals under the government's Mid-Day Meal Scheme (Ramachandran 2019). The programme aims to increase school enrolment and attendance, enhance children's nutritional status, and advance social justice (Ramachandran 2019).

In Mexico, the National School Breakfast Programme (Programa Nacional de Desayunos Escolares, or PNDE) was launched in 1993 with the aim of improving the health and nutrition of children, reducing school dropout rates, and promoting healthy eating habits (Cuevas-Nasu *et al.* 2009). Under the PNDE, eligible students receive a free breakfast every school day which provides learners with as much as 30% of the daily recommended intake of energy, protein, and other nutrients (Cuevas-Nasu *et al.* 2009).

Figure 2.1 shows that most African children who receive school feeding reside in Western Africa (20.1 million), Southern Africa (19.7 million), North Africa (12.9 million), Eastern Africa (11.4 million), and Central Africa (1.3 million). In 2019, 65.4 million children in Africa were anticipated to have received school meals (African Union 2021). The countries with the biggest school feeding programmes are Egypt (11.2 million), Nigeria (9.8 million), South Africa (9.2 million) and Burkina Faso (African Union 2021). The number of children receiving school feeding across Africa shows a significant increase from 2013, when just 38.4 million African children were fed in school (African Union 2021).

School feeding programmes in African countries include Ethiopia's School Feeding Programme, which is a government-led initiative that provides daily meals to primary school learners in food-insecure areas (Destaw *et al.* 2022). The programme seeks to increase school attendance and retention, whilst lowering the incidences of malnutrition (Destaw *et al.* 2022). In Ghana, the School Feeding Programme provides one hot meal each day to children in public primary schools in deprived areas (Destaw *et al.* 2022). The programme aims to reduce hunger and malnutrition, improve school attendance and retention, and boost academic performance (Appiah and Practice 2024).

Additionally, 54 other African countries, including Kenya, Malawi and Nigeria have a "Home-Grown School Meals Programme" (HGSMP) implemented in food-insecure areas which reaches approximately 66 million learners (WFP 2021). The HGSMP provides a daily meal to learners in the majority of the 54 countries to reduce hunger and malnutrition and improve school attendance and retention (WFP 2021). In order to support local economic development and agricultural transformation, HGSMP not only provides daily meals but also includes the purchase of locally farmed food in the design of school lunch programmes (Wineman *et al.* 2022). These initiatives seek to develop a new market for agricultural products and generate employment along the food value chain by satisfying the need for food by using smallholder farmers to supply schools (Nehring, Miranda and Howe 2017; African Union 2021). Likewise, school lunch programmes may help local producers and economies while fostering

long-term food security when they are connected to local food production (WFP 2021). These are but a handful of African nations' school feeding programmes (Falade *et al.* 2012; WFP 2019).

2.3.3 The school feeding programme in South Africa

In 1994, the South African Department of Health launched the Primary School Nutrition Project (PSNP) as part of the Reconstruction and Development Programme (RDP) under former President Nelson Mandela (Van Stuijvenberg and Bulletin 2005). The school nutrition project was proposed in recognition of the fact that hunger can be a barrier to academic success among school learners. It was therefore developed as an intervention to promote a healthy lifestyle and improve children's potential for advancing through the ability to learn (SA DPME 2016).

After being transferred to the Department of Education in 2004, the programme was renamed the National School Nutrition Programme (NSNP) (Buhl 2010). The NSNP is regarded as one of the governments' most effective intervention strategies targeted at improving the food security among historically disadvantaged people, and especially vulnerable children in South Africa (Bassett *et al.* 2012). It has a strong social protection element focused on ensuring that hunger won't be a deterrent for learners attending 'no-fee paying' schools which fall in the 1-3 quintiles, according to the South African public school quintile rankings. The quintile ranking takes into consideration the socio-economic status of the learners and, as such, caters mostly for the less privileged.

In 2024, the NSNP extended the programme to include Early Childhood Development centres (ECDs) and quintile 4 and 5 schools (SA DBE 2024). The extension to include ECDs reinforces the NSNPs commitment to ensuring that younger children (3 to 5 years) receive essential nutritional support. Currently, the NSNP provides learners with free breakfast and lunch meals (SA DBE 2024). The breakfast goes a long way in supplementing 18.0% of the children's RDA, previously provided by the NSNP, and achieving the 25.0% of the RDA that it intends to provide (SA DBE and DPME 2016). The programme aims to provide free, nutritious meals on all 189 school days to approximately 9.6 million learners nationwide (SA DBE 2024).

Furthermore, the NSNP provides a variety of menu offerings that are exclusive to each province, catering to the country's various dietary requirements and cultural diversity (SA DBE 2021). Each province has a unique menu considering regional agricultural produce and cooking customs. This strategy is particularly evident in KwaZulu-Natal, where district-to-district variations in the province's menu are notable. The NSNP has a decentralised system that promotes regional involvement and supports local

economies. Each district highlights distinctive flavours and ingredients that appeal to local populations. This adaptation acknowledges the region's unique cultural history while promoting nutritional well-being.

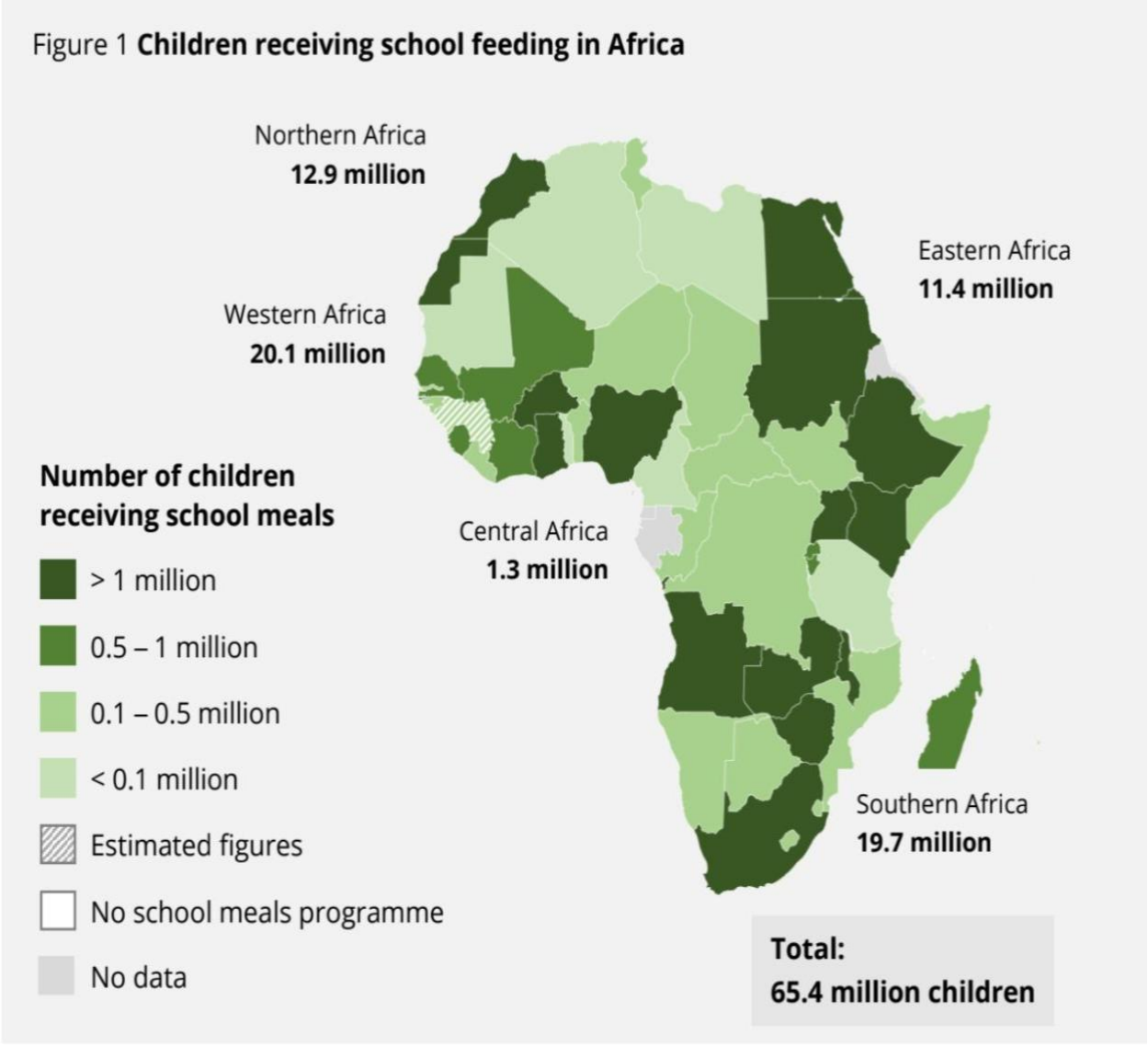
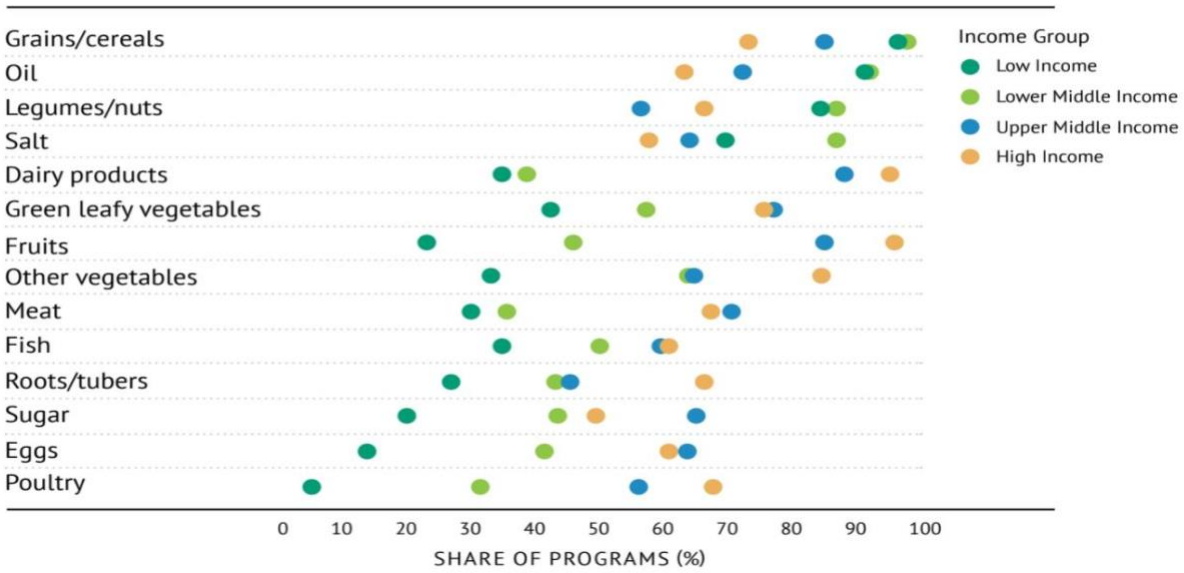


Figure 2. 1: Number of children receiving school feeding across Africa (African Union 2021)

2.3.4 Food items served in school meal programmes globally

The food items served in school meal programmes vary globally and use diverse ingredients accepted locally and culturally (African Union 2018). Figure 2.2 presents the most common food items served in school meal programmes globally in a 2019 survey conducted by the Global Child Nutrition Foundation (GCNF) (2022). The most common food category or item provided to students included grains/cereals



(87% of programmes), followed by oil (78%), legumes (75%), and salt (70%). Fruits and vegetables were provided in 63–65% of the programmes, while animal-source foods were less common.

Globally the school meal programme menus also differ across income classification, as illustrated in Figure 2.2 (GCNF 2022). Grains/cereals, oil, legumes, and salt are more commonly found on the menu of programmes in low-income or lower-middle-income settings. However, all other categories/items are more commonly found on the menu of programmes operating in upper-middle-income or high-income settings (GCNF 2022). Poultry, for example, is served in 69% of programmes in high-income settings but in just 5% of programmes in low-income settings. The gap is even larger for fruits, which are served in 97% and 22.5% of programmes in high and low-income settings, respectively, with a gap of 74.5 percentage points (GCNF 2022).

Figure 2. 2: Food items served in school meal programmes, by income group (GCNF 2022)

Beverages served with meals are an important source of macro- and micronutrients or a source of sugars (GCNF 2022). The common beverages include unsweetened milk served by 37% of the school feeding programmes, milk with added sweeteners (sugar or chocolate syrup), served by 11% of the programmes; unsweetened fruit juice by 20%; and sweetened juice 10% serving of the school feeding programmes respectively (Figure 2.3) (GCNF 2022). Products such as yoghurt drinks are commonly served in the Europe/Central Asia/North American regions school feeding programmes.

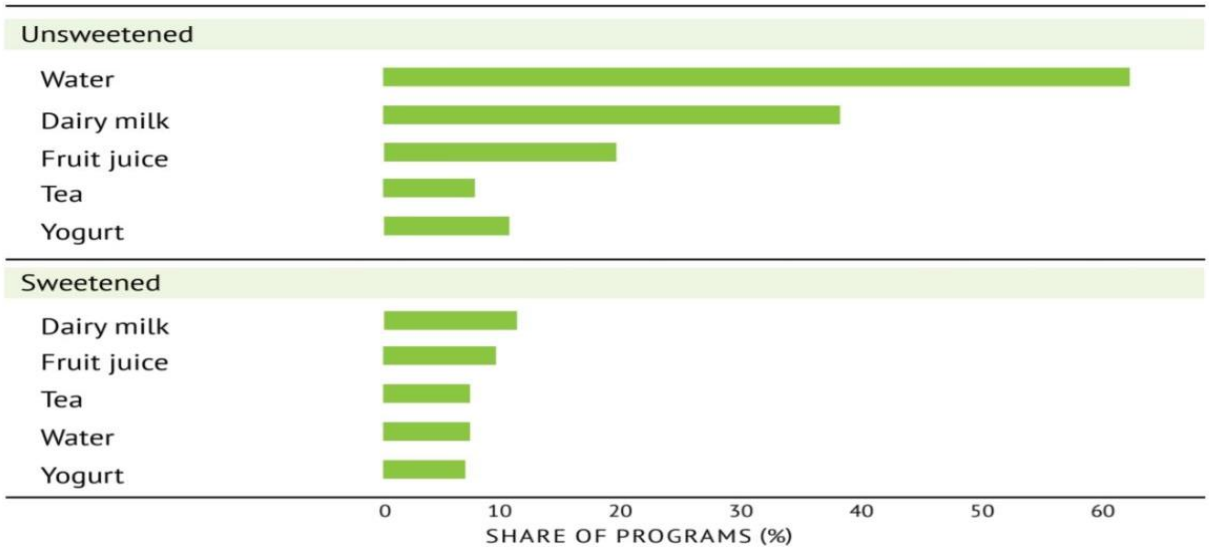


Figure 2. 3: Beverages served in school meal programmes (GCNF 2022)

2.3.5 Food items served in African school feeding programmes

Results from the Global Survey of School Meal Programmes (Figure 2.5), which included 41 African countries, show that grains/ cereals (at 99%), oil (90%), legumes (87%), and salt (78%) form the largest components of the African school feeding programmes food basket contents (Wineman *et al.* 2022). Green leafy vegetables, other vegetables, fish, and tubers were provided in 25-50% of the African countries, while it was uncommon for poultry, eggs, and dairy products to be included. Dairy products were more commonly included on the menu in upper-middle-income countries (at 50% of programmes), compared to lower-middle-income countries or low-income countries (at 18 and 15% of programmes, respectively) (GCNF 2022).

Of the 14 broad food categories, which include eggs, dairy, and fruit, the food baskets of school meal programmes contained an average of just 5.7 categories, as illustrated in Figure 2.4. There was some regional variation, with the average number of food categories highest in Southern Africa (6.8) and lowest in Eastern and Northern Africa (4.5) (GCNF, 2022). The food basket contents also tended to vary by means of the modality through which children received food. On average, in-school meals contained foods from 7.4 categories, in-school snacks contained 1.5 categories (often grains in the form of biscuits or porridge), and take-home rations contained 2.1 categories (often grains and oil). According to the GCNF (2022), countries in Africa that reported having a national policy related to nutrition in school feeding programmes tended to have more diverse school meal menus (with an average of 7.3 food categories) than those with no such policy (average of 5.5 categories).

Category	% of programs
Grains/cereals	99
Oil	90
Legumes, nuts	87
Salt	78
Green leafy vegetables	37
Other vegetables	31
Fish	28
Roots/tubers	27
Sugar	24
Meat	21
Fruits	19
Dairy products	18
Eggs	15
Poultry	9

Figure 2. 4: Food items served in African school meal programmes (Wineman *et al.* 2022)

2.3.6 Cost of school feeding programmes globally

The cost of school meals varies according to the economic status of the country (SA DBE and DPME 2016). Results from a study conducted across 125 countries show that 330.3 million children received school food in 2021(GCNF 2022). The global average for the budget allocated per child who received school food in 2021 was estimated at USD 108 (R1 909.48) (GCNF 2022). The value ranges from USD 18-23 (R318.23-R406.70) per recipient child in lower-income and lower-middle-income countries to USD 400 (R7 072.68) in high-income countries. Across regions, school food investments per recipient child per year in Sub-Saharan Africa are the lowest, on average, at USD 30 (R530.45). The value of investment in South Asia/East Asia/Pacific is estimated at USD 54.5 (R963.53); USD 58 (R1025,67) in Latin America/Caribbean; USD 109 (R1927.55) in Middle East/North Africa; and USD 382 (R6753.57) in Europe/Central Asia/North America (GCNF 2022).

In South Africa, the NSNP relies on many stakeholders, such as the Tiger Brands Foundation and conditional grants from the government (SA DBE and DPME 2016). The NSNP was allocated over eight billion Rands (R8.5 billion) in the year 2023, an increase of 4.6% from the 2021/22 allocation, according to the Minister of Basic Education, Angie Motshekga (South African Government 2022). The (SA DBE 2024) reports that the average cost per meal per learner per day is R3.58 (R748.22 per year), inclusive of breakfast for special, primary and combined schools and R3.79 per meal per learner per day

(R790.02 per year) for secondary schools. Gelli *et al.* (2011) suggest that feeding interventions should not cost less than US$48 (R860.77) per child per year. Therefore, the funds allocated to the NSNP must be increased to accommodate the introduction of breakfast in schools and ensure that the nutritional needs of learners are met. Moreover, the current NSNP budget is supplemented with industry funding, although it comes at the cost of exposing school learners to big company brands.

2.3.7 Strategies for enhancing the effectiveness of the NSNP

Numerous studies have demonstrated that providing breakfast in the morning and a mid-day meal later in the day improves students' academic performance, attendance at school, and nutritional status (Devereux *et al.* (2018); Destaw *et al.* (2022). By providing breakfast, the NSNP can improve the overall nutrition of learners, according to the SA DBE and DPME (2016). Moreover, school feeding initiatives such as providing a meal for children in a well-equipped and well-organised school were more effective than those in poorly equipped and less structured schools (Panchacola 2023). Therefore, FAO, WBG and WTO (2023) suggests that adequate food preparation and storage facilities that are consistent with national standards must be provided to schools. Furthermore, adequate funding should be allocated to school nutrition programmes to ensure access to nutritious meals for all students (Sidaner 2022). Additional funds can be secured through government subsidies, community partnerships, and grant programmes. Nutrition coordinators should receive developmental training on time and human resource management to help them manage food handlers and educate them simultaneously. Principals and teachers should be relieved of the responsibility of overseeing the nutrition programme on a daily basis by appointing nutrition coordinators (Mawela and Van den Berg 2020).

According to Devereux *et al.* (2018), a food safety plan that can be used at all schools that provide NSNP meals should be developed in collaboration with the DBE and the Department of Health. Infection control measures, such as educating and certifying food handlers about incorrect food preparation and storage, meticulous hand washing, and providing paid sick leave to food handlers who have gastroenteritis, should be part of the food safety plan (Devereux *et al.* 2018). Additionally, in order to determine the effect of school feeding on certain outcomes and to offer a foundation of evidence for suggestions for improved programming and decision-making, a more robust monitoring and evaluation system is required for school feeding programmes in South Africa (SA DBE and DPME 2016). Additionally, South Africa may benefit from the experiences of other nations, like Brazil, Lesotho, and Namibia. For example, they can learn from alternative approaches like "home-grown school feeding" and local procurement (Devereux *et al.* 2018).

2.4 Importance of breakfast

According to Adolphus, Lawton and Dye (2013), breakfast is frequently regarded as the most significant meal of the day. A major advantage of breakfast is that it improves cognitive performance (Masoomi *et al*. 2020). According to Yao, Liu and Zhou (2019), skipping breakfast can lead to decreased attention, memory, and problem-solving skills in children and adolescents. However, a healthy breakfast has been demonstrated to enhance cognitive functions, such as memory and focus, which are critical for classroom learning (Peña-Jorquera *et al.* 2021). In addition to cognitive benefits, eating breakfast has been linked to better academic performance (Adolphus, Lawton and Dye 2019). A study by Yao, Liu and Zhou (2019) found that students who ate breakfast regularly had higher grades and performed better on standardised tests compared to those who skipped breakfast. This suggests that breakfast can provide students with energy and nutrients, which alleviates feelings of hunger that may hinder the learners from succeeding academically (Gibson-Moore, Spiro and Stanner 2023).

Furthermore, breakfast plays a crucial role in regulating mood and behaviour among school learners (Rani, Dharaiya and Singh 2021). Research has shown that skipping breakfast is associated with irritability, anxiety, and poor behaviour in the classroom (González-Garrido *et al.* 2018; Lee *et al.* 2019). Eating breakfast can help stabilise blood sugar levels, which can contribute to better mood regulation and behaviour throughout the day (Rai *et al.* 2023).

Moreover, breakfast has a substantial influence on general health and well-being (Daneshvar 2023). A nutritious breakfast can provide vital nutrients, including vitamins, minerals, and fibre, which are important for growth and development in children and adolescents (Moreno-Aznar *et al.* 2021a). Eating breakfast has also been associated with a decreased incidence of obesity and chronic conditions, including diabetes and heart disease, later in life (Singh *et al.* 2022).

Globally, several countries have a school breakfast programme that provides different meals. For instance, school breakfast programmes in Brazil, Costa Rica and the Dominican Republic provide hot meals prepared with cereals (FAO 2019b). In Ecuador, learners are provided with a fortified flavoured beverage named “colada” and granola/cereal bar, cookies or filled cookies for breakfast (FAO 2019b). The school breakfast programme in the United States consists of whole grain cereals, fruits, and milk (USDA 2022). Guatemala offers fortified cereal-based drinks, milk or fortified porridge, hot meals prepared with cereals (rice, pasta), legumes, fruit, vegetables and/or eggs (FAO 2019b). In Honduras, breakfast consists of meals prepared with cereals (corn, rice) or fortified flour, legumes and oil, with some schools offering milk, fruit, and fresh vegetables (FAO 2019b).

Furthermore, Mexico offers a cold, ready-to-eat breakfast that includes skimmed milk, cereal-based products (cookies, cereal bar), and fresh or dehydrated fruits or culturally accepted chicken tacos with tomato as a hot breakfast meal (FAO 2019b). Australia provides nutritious breakfast items such as cereal, milk, canned fruit, Vegemite, jam, fresh fruit, and bread to hungry school learners in registered schools in South Australia and the Northern Territory from food banks (Food Bank 2023). Paraguay offers fortified or plain whole milk and cereal-based products such as cookies, bread, crackers, rosquilla [cookie], muffins or fruits (FAO 2019b). Likewise, in Peru, breakfast consists of fortified milk or milk with cereals such as oatmeal, and a bread-like product with cheese, egg or butter (FAO 2019b).

In contrast, African nations such as Lesotho, Malawi and South Africa offer maize, millet, or sorghum porridge as a morning meal (Drake *et al.* 2016). These programmes illustrate great focus on offering a variety of healthy foods that can meet the learners' nutritional requirements during the school day (FAO 2019b).

2.5 The significance of millets in sustainable agriculture

Millets are diverse cereal grains, including major varieties like sorghum and pearl millet, and lesser-known types like foxtail and kodo millet, with pearl millet and sorghum indigenous to South Africa (SA DAFF 2013; FAO 2023). Millets' short growth season and exceptional resilience to arid conditions make them great rotating cover crops. Compared to C3 species like wheat and rice, millets are C4 plants that are more efficient at photosynthesis, water use, yield, and the production of sugar molecules in hot, dry, temperate, tropical, and subtropical climates with less rainfall and drought (Rao 2021). Millets have gained little attention in agricultural research, legislation, and markets, in spite of their many advantages (Kheya *et al.* 2023). Numerous traditional knowledge systems related to these crops have been lost, and family farmers have been disincentivised to continue cultivating them (FAO 2023). Given the significance of millets, the United Nations Food and Agricultural Organisation (FAO) announced the year 2023 to be the "International Year of Millets" (IYM) (Kheya *et al.* 2023).

Since millets provide nourishment and food security, the IYM offers a chance to recognise, enhance, and promote their significance in indigenous peoples' food and knowledge systems. Millets symbolise the close ties that many indigenous peoples have to their ancestral lands, territories, and resources. Indigenous nomads, pastoralists, hunter-gatherers, and local farmers all eat the grains, which supports the diversity and distinctiveness of their food systems. Millets guarantee the expansion of the global food supply, which is essential for changing agrifood systems in which Indigenous Peoples are crucial.

However, millets also provide a chance to honour indigenous wisdom and the possibility of biodiversity conservation cooperation between scientists and indigenous peoples. Additionally, the IYM 2023 supports the 2030 Agenda for Sustainable Development of the United Nations, namely the objectives of Climate Action and Life on Land, Decent Work and Economic Growth, Zero Hunger, Good Health and Well-Being, and Responsible Consumption and Production (FAO 2023).

2.6 Pearl millet

Pearl millet, or *Pennisetum glaucum (L.),* is a significant grain that ranks sixth in terms of production worldwide, after sorghum, barley, rice, wheat, and maize (Satyavathi *et al.* 2021). Pearl millet is known as "Nyalothi, Ntweka, Amabele, Unyaluthi, Unyawoti, Unyawothi Inyawuthi, Muvhoho, Babala, Manna, Leotja, Mhunga, Bulrush millet and Bajra". It is a modest hero in the world of grains, and it has supported millions of people for generations (SA DAFF 2013). A native of the Sudan (South of the Sahara Desert), this crop was domesticated on the southern border of the Sahara more than 4,000 years ago before moving to East Africa and India (Manning *et al.* 2011).

According to Govindaraj and Pujar (2023), India leads the world regarding the area cultivated for pearl millet and its output. The FAO (2023) estimates that 46.53% of millet produced worldwide is produced in Africa, and 49.66% in Asia. The nations of Oceania (Australia, New Zealand, etc.), America, and Europe produce 2.48%, 1.20%, and 0.12% of the world's millet, respectively. The provinces of KwaZulu-Natal, the Free State, and Limpopo in South Africa produce pearl millet (SA DAFF 2013). According to a study conducted by Kesa *et al.* (2023) in the Gauteng province of South Africa, 12.3% of participants reported eating pearl millet, and 21.7% indicated that they were familiar with it. The nutritional shift from traditional diets, mostly centred on locally grown foods, to a Western diet is the reason for the low consumption of pearl millet (Kesa *et al.* 2023).

Pearl millet is vital for food and nutritional security because of its many benefits, including early maturation, drought tolerance, low input requirements, and a high degree of resistance to biotic and abiotic challenges (Baby *et al.* 2020). To elaborate, FAO (2023) states that pearl millet is mostly grown on marginal soils with erratic rainfall because of its innate ability to endure and tolerate environmental challenges, including heat, salinity, and drought. Moreover, because of its deep root systems, pearl millet can reach water from subsurface levels which other plants cannot (FAO 2023).

Additionally, pearl millet is less dependent on chemical fertilisers and exhibits great photosynthetic efficiency and exceptional production and growth in low-nutrient soil conditions (Satyavathi *et al.*

2021). All of these qualities are quite beneficial when considering how climate change and global warming may affect agricultural output in the future. Therefore, the emphasis should be on creating food items from pearl millet to establish it as a viable future crop option (Baby *et al.* 2020).

2.6.1 Composition of pearl millet

The kernel structure of the pearl millet grain is depicted in Figure 2.5. Pearl millet's kernel structure is comparable to that of sorghum, consisting of the pericarp, germ, and endosperm (refer to Figure 2.5). The pearl millet kernel is a caryopsis, similar to sorghum, in which the pericarp is completely joined to the endosperm (Hassan, Sebola and Mabelebele 2021).

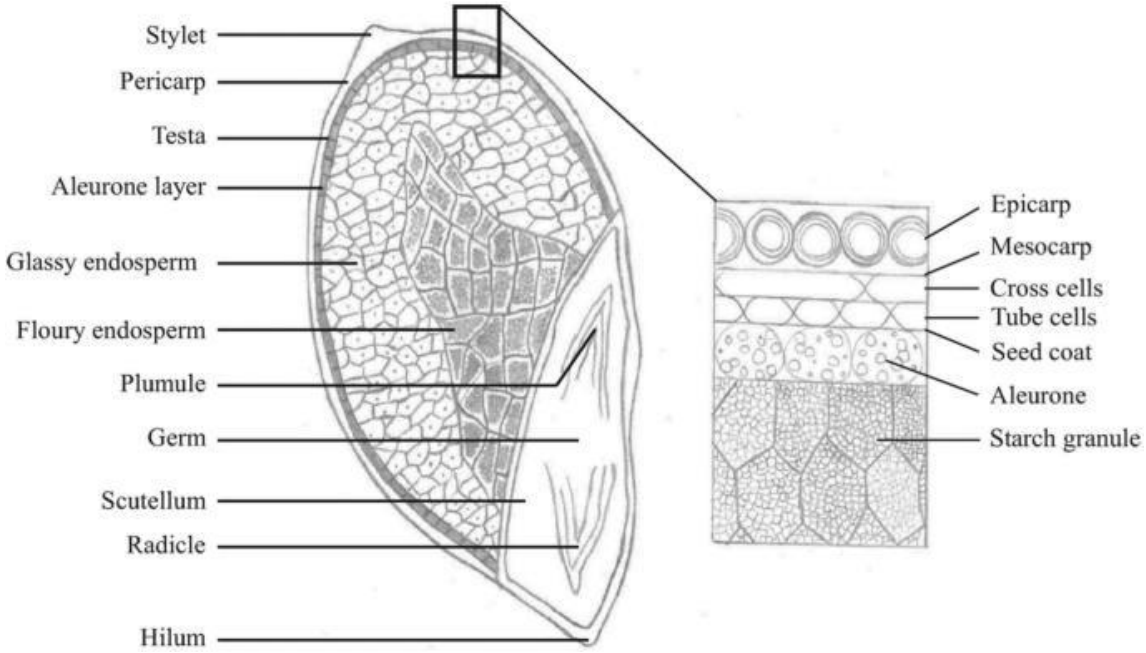


Figure 2. 5: Grain structure of pearl millet (Hassan, Sebola and Mabelebele 2021)

Pearl millet is mostly made up of carbohydrates (mostly starch) (56–65%), similar to wheat (69%), but less than maize (78%) and rice (85%) (Krishnan and Meera 2018). About 56–65% of the kernel is made up of starch, which is composed of 20–22% amylose; the remaining 2.6–2.8% of the grain is made up of free sugars. The adequate composition of starch and amylose determines the functional properties of pearl millet starch like gelatinisation (important for the food industry) and hypoglycemic properties (Annor *et al.* 2017). Sucrose is the primary sugar found in pearl millet. According to Annor *et al.* (2017), pearl millet has a high fibre content (11.9–13.3%), which serves as an essential modulator of cholesterol

levels and bowel health. Additionally, pearl millet is widely recognised as having a low Glycaemic Index (GI), helping to manage diabetes (Anitha *et al.* 2021b). Pearl millet has less carbohydrate (67%) than rice (84.9%), maize (78.1%), and is comparable to wheat (68.85%) (Chauhan *et al.* 2018). Compared to the germ of sorghum (17.4% in millet and 9.8% in sorghum), the germ of pearl millet makes up a significantly higher percentage of the entire kernel. This distinction explains why pearl millet has less protein, fat, and carbohydrate than sorghum. About 56–65% of the kernel comprises starch and 20–22% amylose; the remaining 2.6–2.8% of the grain contains free sugars. Sucrose is the primary sugar found in pearl millet. According to Hassan *et al.* (2021) pearl millet has a high fibre content (8-9g/100g). Remarkably, most dietary fibre is insoluble; pearl millet has 8–15 times more αamylase activity than wheat (Yadav *et al.* 2021). Additionally, pearl millet has a low GI (56.6), making it suitable for the management of diabetes (Anitha *et al.* 2021c).

Protein is the second main ingredient in pearl millet. Compared to rice (8.6%) and maize (9.2%), pearl millet has a protein content that is similar to sorghum (10.7%) (Adebiyi *et al.* 2017). Pearl millet protein is rich in glutamic acid, a non-essential amino acid that functions as a neurotransmitter or a precursor for γ-aminobutyric acid (Adebiyi *et al.* 2017). For those who are allergic to wheat, pearl millet is the best grain since it is gluten-free and the only one that maintains its alkaline qualities after cooking (Meena *et al.* 2024). These results suggest that pearl millet provides people with a wholesome and easily digested supply of proteins and calories.

Grain pearl millet has a relatively high lipid content (6.4%), about twice that of maize (3.3%) and sorghum (3.4%) (Annor *et al.* 2015). Wrigley *et al.* (2016), Annor *et al.* (2015), and Hassan, Sebola and Mabelebele (2021) state that the main fatty acids found in pearl millet grain are palmitic acid (C16:0), which is 20–21%; oleic acid (C18:1), which is 21–27%; and linoleic acid (C18:2), which is usually 39–45%. However, because unsaturated fatty acids are prone to oxidation, this species' high lipid content may have detrimental consequences on the durability of goods like flour (Tiwari *et al.* 2014). According to Taylor and Emmambux (2008), the germ makes up around 21% of the grain, which results in a high lipid concentration. Grain pearl millet has a relatively high lipid content (6.4%), about twice that of maize (3.3%) and sorghum (3.4%), but less than that of oats (7.6%). However, specific differences lead to comparisons that differ from those mentioned above. For instance, Belton and Taylor (2002) discovered that certain cultivars of pearl millet had lower lipid concentrations than maize.

According to Hassan, Sebola and Mabelebele (2021), pearl millet contains significant amounts of thiamine (B1), riboflavin (B2), niacin (B3), folate (B9), lipid-soluble vitamin E and vitamin A. These

vitamins are located in the germ. Thiamine is essential for converting carbohydrates into energy (Kajla, Ambawat and Singh 2020), while riboflavin is crucial in energy production and DNA synthesis (Mosegaard *et al*. 2020). The presence of niacin is important for energy metabolism (Kajla, Ambawat and Singh 2020), while folate makes pearl millet a biofortificant against the anaemic population (Anitha *et al.* 2021a). Additionally, pearl millet may also provide benefit from its vitamin E content, an antioxidant that may prevent triglyceride degradation and shield cells from free radical damage (Hassan, Sebola and Mabelebele 2021).

Regarding mineral content, pearl millet is an excellent source of several essential minerals, including, iron, zinc, magnesium, phosphorus and potassium (Krishnan and Meera 2018; Meena *et al.* 2024)). Calcium is crucial for bone health and development (Nishane and Dachewar 2023), while iron is essential for healthy red blood cells (Singh, Goyal and Sheth 2014). According to Ambati and Sucharitha (2019), magnesium can help treat migraines and asthmatic patients' respiratory issues. On the other hand, phosphorus is necessary for bone growth and development as well as the production of ATP, our body's energy currency (Dayakar Rao *et al.* 2017). Potassium helps regulate blood pressure and support overall cardiovascular health (Biradar *et al.* 2024), while zinc is essential for immune function and protein synthesis (Dardenne and Bach 2020). Other phytonutrients found in pearl millets include apigenin, flavonoids, lignin, and myricetin, which have antifungal and antiulcerative properties and help prevent cardiovascular disease and breast cancer (Thakur and Tiwari 2019). Moreover, pearl millet has been called a nutri-cereal because of its phytochemical nutraceuticals content, which might be crucial in combating malnutrition and guaranteeing food and nutritional security (Kulkarni, Sakhale and Chavan 2021).

2.6.2 Phenolic compounds and antioxidant activity in pearl millet

Pearl millet has several anti-nutritional components (phytate, tannins, and polyphenols) in addition to its nutritional benefits (Krishnan and Meera 2017). These elements reduce the absorption of minerals in the gastrointestinal system, lowering their bioaccessibility and bioavailability (Nour and Ahmed 2014). In agreement, Krishnan and Meera (2017) highlight that phytate and polyphenols in pearl millet have generally been associated with reduced iron and zinc bioaccessibility. Moreover, polyphenolic pigments in pericarp, aleurone and endosperm areas may cause the development of an unpleasant grey colour and taste to the pearl millet products (Rathi, Kawatra and Sehgal 2004). This has led to the investigation of processing methods like decortication, soaking, lactic acid fermentation, sprouting and thermal treatment which have been investigated to improve the nutritional availability and storage stability of

pearl millet flour as well as the products (Rani *et al.* 2018). Additionally, research programmes have focused on promoting biofortification of pearl millet with zinc and iron (Ullah *et al.* 2016).

2.6.3 Pearl millet-based food products

2.6.3.1 Traditional application

Pearl millet is used in Africa and India to make a variety of traditional local foods, including porridges, flatbreads, couscous, sweets, and alcoholic and non-alcoholic drinks, including “pombe” (a fermented beer), “pito” (a fermented beer), “kununzaki” (a fermented non-alcoholic drink), “mahewu” (a fermented non-alcoholic drink) and “oskikundu” (a fermented non-alcoholic drink) (Adebiyi *et al.* 2018; Dias-Martins *et al.* 2018). The majority of these products are made in homes or small factories and used in primary meals. “Fura” is a traditional Nigerian dish prepared from fermented and non-fermented pearl millet flour and spices that is formed into a ball and cooked in traditional Nigerian homes (Dias-Martins *et al.* 2018). According to Filli *et al.* (2013), it is either mashed in water before being eaten as porridge or eaten with yoghurt (called "nono"), depending on the location.

2.6.3.2 Porridge

The most popular pearl millet food product is porridge (called “ben-saalga”, “uji”, “ugali”, “oko”, “tõ”, “obushera”, “koko”, “bogobe”, “tchobal”, “bouillie”, and “kambu koozh”), which may be made from pearl millet flour either fermented or unfermented (Adebiyi *et al.* 2018). The consistency can range from thick to thin depending on the flour percentage (10% to 30%). Various porridges may be made by cooking flour in hot water while stirring vigorously. Moreover, adding tamarind extract, lemon juice, or potash can significantly alter the flavour and pH of these products (Kajuna and Mejia 2001; Wrigley *et al.* 2016).

2.6.3.4 Flatbreads and couscous

Flatbreads (called *Chapati, Rotti* or *Rotla* in India) are a popular pancake-like gluten-free food produced from unfermented pearl millet flour in warm water (Siroha, Sandhu and Kaur 2016) or with fermented pearl millet flour like Lohoh from Saudi Arabia (Osman 2011). Depending on the area, these flatbreads can be prepared on a hot plate (tawa), clay griddle or wood fire stove. During meals, they are typically eaten with spicy sauces (Sudan) or hot pickles (India). Also called semolina, couscous is an integral part of North African cuisines. However, couscous (*karaw; thiakri, thiacry*) is traditionally cooked using flour or decorticated pearl millet grains in Senegal and Mali. This couscous is frequently eaten with yoghurt or vegetables (Taylor, Barrion and Rooney 2010).

2.6.3.5 Confectionery and snacks

Pearl millet grains may be used to make sweets and salty goods (Yuvarani and Anitha 2016). Small sweet balls called *ladoo* and *dakuwa* are made from roasted pearl millet grain flours and are traditionally eaten in India and Nigeria, respectively. Potential components like malted wheat and popped pearl millet grain can be added to those sweets to boost their nutritional value, claim Nkama, Gbenyi and Hamaker (2015).

2.6.3.6 Beverages

In Nigeria, pearl millet is also used to make fermented goods, including beer, *Ontaku*, and *Fura* from parboiled grains (Embashu and Nantanga, 2019). Similarly, a pearl millet-based traditional beer called *Omalodu* is produced in Namibia (Misihairabgwi and Cheikhyoussef 2017).

2.6.3.7 Availability in the South African market

In South Africa, pearl millet is becoming more widely available in retail establishments. For instance, in 2017, Woolworths South Africa introduced a line of power grain breakfast bars, one of which was made with pearl millet, cinnamon and dried apple. Health Connections Whole Foods© offers hulled or dehusked non-GMO millet, and Nature's Choice© includes millet flour in their product range. While this represents a positive step, pearl millet remains underutilised in South Africa despite its commercialisation potential. Manufacturers of food products ought to raise awareness of these goods.

2.7 Sorghum

After wheat, rice, maize, and barley, sorghum *(Sorghum bicolour (L.) Moench)* is the fifth most significant cereal crop (SA DSI 2021). Sub-Saharan Africa is where this crop first appeared and was domesticated before spreading to China and India (De Wet 1978). There are a number of closely related wild sorghum species in sub-Saharan Africa (Ananda *et al.* 2020). According to recent research, the oldest evidence of domestication dates to about the fourth millennium BC in eastern Sudan (Winchell *et al.* 2017).

According to the United States Department of Agriculture (2024), sorghum output in 2022–2023 was 25.44 million tonnes in Africa and 55.32 million tonnes worldwide. Sorghum grows indigenously in the provinces of KZN, the Free State, the North West, the Northern Cape, the Eastern Cape, and Gauteng in South Africa (SA DAFF 2013). Despite being a popular component for successful product development in the food and beverage sectors, sorghum consumption remains low in South Africa (Dunjana *et al.* 2022; Aguiar *et al.* 2023).

Sorghum is well-known for its broad flexibility and robust resilience to different biotic and abiotic stressors (Huang 2018; Zhang *et al.* 2019). This crop is widely popular because it has (i) a variety of end uses, including human food, livestock feed, biofuel, and fodder; (ii) high returns; (iii) greater resilience to unfavourable environmental conditions than many other cereal crops; and (iv) performs well under water and temperature constraints, particularly in marginal lands (Huang 2018; Zhang *et al.* 2019; Hao *et al.* 2021). Sorghum has received interest as a possible "star" crop to address the issue of global food security because of these attributes (Huang 2018; Hao *et al.* 2021; Ndlovu, Van Staden and Maphosa 2021).

2.7.1 Proximate composition of sorghum

Figure 2.6 illustrates the main structural components of the sorghum grain, which are the pericarp (outside layer/bran), germ (smallest innermost section), and endosperm (centre starchy and largest part), with the endosperm being the largest (Sautier *et al.* 1989).

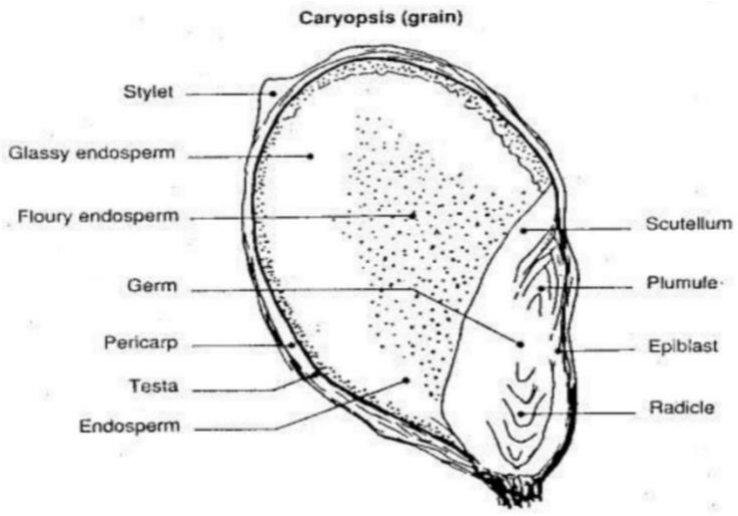


Figure 2. 6: Structure of sorghum grain (Sautier *et al.* 1989)

Compared to other cereals, sorghum's proximate composition has a unique nutritional profile. Sorghum's main structural components are the pericarp (outside layer/bran), germ (smallest innermost section), and endosperm (centre starchy and largest part) (refer to Figure 2.6), with the endosperm being the largest (Awika 2017; Serna-Saldivar and Espinosa-Ramírez 2019). According to Serna-Saldivar and Espinosa-Ramírez (2019), the endosperm of sorghum is mostly composed of starch and protein, whereas the pericarp is rich in fibre and the germ contains protein, fat, and minerals. The protein, which ranges from 6 to 18% in the endosperm, germ, and pericarp, is mostly made up of fractions of acid-alkali soluble

glutelins, alcohol-soluble prolamins, salt-soluble globulins, and water-soluble albumins (Awika 2017). According to Singh, Sharma and Singh (2017), the solubility of sorghum protein is important for product development since it affects nutritional quality, flavour, and texture. Increased solubility improves sorghum flour's functional qualities, enabling it to be used in a wider range of culinary applications and enhancing the performance of the final product (Singh, Sharma and Singh 2017). While glutelins and prolamins are found in the endosperm, albumins and globulins are found in the germ (Bean *et al.* 2019). Sorghum's proximate composition has a unique nutritional profile compared to other cereals. According to Serna-Saldivar *et al.* (2019), the endosperm of sorghum is mainly composed of starch and protein. In contrast, the pericarp is fibre-rich, and the germ contains protein, fat, and minerals.

According to Ratnavathi (2019), the fat content of sorghum grain, which ranges from 2.1% to 7.6%, can surpass the normal amounts observed in rice and wheat. Furthermore, the primary sources of lipid content in sorghum are the aleurone layers and the germ (Kulamarva, Sosle and Raghavan 2009). The majority of the crude fat contains oleic acid (31.1- 48.9%) and linoleic acid (1.7-3.9%), which constitutes 80% of the lipid content (Awika and Rooney 2004), stearic acid (1.1-2.6%), palmitic acid (11.7-20.2%) and palmitoleic acid (0.4-0.6%) (Stefoska-Needham *et al.* 2015). Furthermore, decortication considerably lowers the amount of dietary fibre in sorghum, which is found in the pericarp and endosperm cell walls (Serna-Saldivar and Espinosa-Ramírez 2019).

Moreover, sorghum contains B-complex vitamins, including pyridoxine, thiamine, riboflavin, biotin, and niacin (Kimani 2022). Interestingly, the mineral content of sorghum is similar to that of millet; it is lower in wheat and greater in maize (Stefoska-Needham *et al.* 2015). According to Awika (2017), the germ and pericarp have a substantial micronutrient makeup that includes potassium and phosphorus. The bioavailability of phosphorous is impacted by the phytic content, despite the fact that fermentation and malting have been successful in raising the mineral content (Serna-Saldivar and Espinosa-Ramírez 2019).

In addition to being rich in vitamins and minerals, sorghum is a remarkable source of antioxidants. Whole-grain sorghum, particularly the red, brown, and black varieties, is a rich source of antioxidants, which provide defence against free radicals (Awika and Rooney 2004). The sorghum grain contains phenolic compounds, flavonoids, condensed tannins, stilbenes, and lignins (Xiong *et al.* 2021). The majority of these phytochemicals are found in the bran fraction and have been demonstrated to offer a number of potential health advantages, including anti-inflammatory, anti-cancer, cholesterol-lowering, and antidiabetic effects (Dykes 2019).

Moreover, sorghum also contains anthocyanins, which are phytochemicals that contain antioxidant, cardiovascular protection, anti-inflammatory, anti-cancer, and hypoglycemic properties (Kumari *et al.* 2021; Kowalczyk *et al.* 2024). By lowering oxidative stress in the body, antioxidants can lower the risk of several chronic illnesses, such as type 2 diabetes and heart disease (van der Schaft *et al.* 2019; Młynarska *et al.* 2024). Compared to other cereal grains, sorghum exhibits more advantages to the gut microbiota, including anti-inflammatory, antioxidant, antithrombotic, and antidiabetic properties due to its bioactive chemicals (de Morais Cardoso *et al.* 2017; Gamage *et al.* 2017; Anunciação *et al.* 2018; Palavecino *et al.* 2019).

Additionally, people with coeliac disease can benefit greatly from sorghum because it is gluten-free (Taylor and Awika 2017). However, several nations still cultivate sorghum primarily for animal feed, even though eating it has health advantages for humans (Bianco-Gomes *et al.* 2022).

2.7.2 Phenolic compounds and antioxidant activity in sorghum

Phenolic compounds found in plants have antioxidant properties and may be beneficial to health by serving as a natural defence against oxidative stress and illness (Serna-Saldivar and Espinosa-Ramírez 2019). According to Girard and Awika (2018), the predominant compounds that make up a significant portion of the cell wall structure of cereal grains are phenolic acids. As demonstrated by their ability to scavenge free radicals, the phenolic compounds have enhanced antioxidant activity (Stefoska-Needham *et al.* 2015).

Phenolic compounds, which are available in free form and readily extractable in fruits and vegetables, have a significant impact on colour and flavour. However, in sorghum, they are esterified to the cell wall and are not readily extractable (Awika and Rooney 2004; Awika 2017). According to Duodu and Awika (2019), 70% of sorghum is made up of bound phenolic acid, which is primarily responsible for the widespread crosslinking characteristics seen in the cell wall of the crop. As with the majority of monomeric phenolic compounds found in nature, the unbound form of phenolic acids is limited in sorghum (Dicko *et al.* 2006; Duodu and Awika 2019).

Flavonoids are present in coloured sorghum genotypes (except in white sorghum) and possess strong antioxidant qualities (Duodu and Awika 2019). Cereal has comparatively fewer flavonoids than fruits and flowers, which help produce the pigmentation necessary for pollination (Girard and Awika 2018). Compared to other cereal grains, sorghum has higher concentrations of a variety of flavonoids (Awika and Rooney 2004).

According to Awika and Rooney (2004), oxidative stress is a major contributing factor to non-communicable illnesses, including obesity, cardiovascular disease, and colon disease. Sorghum is becoming more popular because of its strong antioxidant activity in vitro compared to other cereal grains (Awika and Rooney 2004). The magnitude of the in vivo positive impact of phytochemicals in the human diet is yet unknown.

2.7.3 Sorghum-based food products

2.7.3.1 Beverages

Historically, beverages derived from sorghum were the most extensively studied product (Aguiar *et al.* 2023). Beer was the most popular beverage, manufactured and consumed throughout China and Africa. When Davana and Revanna (2021) created beers with varying percentages of sorghum and barley (40, 60, and 100% of each cereal), the 60% sorghum beer scored the highest on the mouthfeel scale. Due to its lower planting costs, sorghum has the potential to be used as an alternative cereal in beer production, particularly for gluten-free beers that benefit those who cannot tolerate gluten. The sorghum beer was comparable to commercial beer made with barley, demonstrating its potential as a cereal alternative.

In addition to beer, sorghum is used in the production of juice. Sharma *et al.* (2021) used sweet sorghum to create a juice. To eliminate the insoluble particles, the juice was centrifuged for 10 minutes at 6000 RPM after being sterilised by heating it to 90 °C for 15 minutes. The fermentable sugars in the juice were transformed into functional carbohydrate molecules by Sharma *et al.* (2021), creating a well-liked functional beverage high in prebiotic oligosaccharides, which may support intestinal health. This demonstrates the potential of sweet sorghum juice as an inexpensive raw material for creating novel beverages with practical appeal.

Mazumdar *et al.* (2012) and Cséfalvay and Bakacsi (2019) looked at using sweet sorghum juice to make a syrup which was more palatable to customers and had higher nutritional value. Sorghum syrup can be utilised as a substitute for sugar to sweeten various food items, making it an interesting product. The syrup, created from sweet sorghum juice, may be further fortified or combined with other fruit juices or concentrates, making it potentially helpful in creating commercial drinks, according to the referenced authors. The syrup may also be combined with protein concentrates or other beverages, which enables the creation of goods with better nutritional value that the nutraceutical market would embrace because of the health benefits that sorghum offers (Xu, Wang and Zhao 2021; Khoddami *et al.* 2023; Taylor and Duodu 2023).

When Rashwan *et al.* (2021) reviewed various technological processing techniques, including soaking, germination, fermentation, thermal processes, and irradiation, they found that fermentation was the main treatment that improved the nutritional value of sorghum-based products. They also used a combination of soaking, germination, and nixtamalisation (soaking and cooking in limewater), showing how these techniques contributed to producing sorghum-based foods with a higher nutritional value.

2.7.3.2 Bakery products

Research on creating sorghum-based bakery products, mainly gluten-free bread, has increased since 2014, resulting from the increased demand for gluten-free products in people with coeliac disease and those who prefer healthy products. Aguiar *et al.* (2023) published a systematic review over the last decade assessing a massive sample, including gluten-containing (n = 7122) and gluten-free food products (n = 3153) from around the globe. Although there is no concise report currently available on what these products contain and how they label gluten-free bread across the world, this study intended to shed light on the nutritional value of these products. According to Aguiar *et al.* (2023), gluten-free bread (n = 935) has a significant degree of variability in its carbohydrate (14 to 84%), fat (1 to 19%), protein (0 to 11%), sugar (0 to 24%), and dietary fibre (0 to 17%) contents due to the product's various raw ingredients and additions, according to the label review. It is nonetheless acknowledged that these gluten-free goods are low in protein, heavy in fat, and occasionally lacking in dietary fibre. As noted by some authors, such as Centeno *et al.* (2021), using up to 75% white sorghum flour (BRS501 genotype without tannins) combined with 25% potato starch or using 100% bronze sorghum flour (BRS332 genotype with tannins) can improve not only the nutritional content but also the physical and sensory properties of gluten-free bread.

The first papers related to the use of sorghum in bakery products have appeared quite recently, since 2014, triggered by the growing popularity of gluten-free products based on sorghum, especially bread, resulting from the increased demand for gluten-free products in people with coeliac disease or cystic fibrosis, or those who prefer healthy products. Aguiar *et al.* (2023) published a systematic review over the last decade assessing a massive sample, including gluten-containing (n = 7122) and gluten-free food products (n = 3153) from around the globe.

Comparing sorghum-based goods to other grain products, Khoddami *et al.* (2023) found that the former had poorer sensory acceptability. The presence of tannins and other phenolics in sorghum-based bread may have a detrimental influence on acceptability, as noted by de Oliveira *et al.* (2022), who looked at

the acceptance of gluten-free bread made with various sorghum types/varieties and flours. However, while gluten-free bread made using red sorghum BRS 332 flour was well received, the authors highlight the necessity of identifying the best type of bread for each sorghum variety.

In addition to improving the nutritional quality and fostering consumer acceptance, sorghum also contributes to the good physical characteristics of cakes. Cakes made with sorghum have flavours, textures, colours, and odours that are very similar to those of traditional products made with wheat or rice flour (Ari Akin *et al.* 2019). Cayres *et al.* (2020) showed that sorghum may be utilised as the primary component in a food product by creating gluten-free cakes using 87.8% red sorghum wholegrain flour (flour base). According to Centeno *et al.* (2021), Yu *et al.* (2020), and Johnson *et al.* (2021), sorghum with a white pericarp can be readily substituted for flours such as wheat without affecting colour. Red and brown genotypes can also be used to produce chocolate-containing products, which results in a darker product with a more appealing appearance (Yu *et al.* 2020; Centeno *et al.* 2021; Johnson *et al.* 2021).

Cookies and biscuits can also benefit from sorghum because both gluten-containing and gluten-free versions can utilise this ingredient to boost nutritional quality. Yu *et al.* (2020) created biscuits using wheat flour enhanced with whole and extruded sorghum flour. Adding 80% extruded sorghum flour to wheat flour biscuits was shown to boost the resistant starch content of these items, with this sample receiving greater sensory acceptability than the control sample made with 100% wheat flour. Cervini *et al.* (2021) created gluten-free cookies enhanced with a unique resistant starch component derived from annealed white sorghum. The use of resistant starch is noteworthy because the partial replacement of flours such as wheat flour with this component can be a viable alternative to commercially developed products comprising starches with low digestibility and high fibre content. Despite the good effect on nutritional quality, the biscuits created with resistant starch had a low texture score and general acceptability, being more challenging than the control sample made with a 100% commercial gluten-free flour mixture.

2.7.3.3 Pasta Products

Regarding pasta products, Johnson *et al.* (2021) discovered that using up to 75% black sorghum flour in combination with wheat flour can result in noodles that are more nutritionally valuable, have a higher total polyphenolic content, a higher antioxidant capacity, and sensory acceptability that is on par with the standard sample made with 100% wheat flour. de Oliveira *et al.* (2022) used 24.4% white (commercial and CMSXS 180), red (BRS 330 and BRS 332), or brown (BRS 305 and 1167048)

sorghum flour to study the usage of sorghum to create gluten-free pasta. The sensory investigation revealed no significant variation in preference for a specific pasta hue. However, the samples made with the BRS 305 (dark colour and high tannin content) were the least acceptable, with lower acceptability for the taste attribute, more astringency, and a sandy sensation on the tongue. This might be due to the greater tannin content of this sorghum genotype and the endosperm's more farinaceous nature.

2.7.3.4 Sorghum-based ingredients

Sorghum flour is frequently used to create new products, but research also highlights the importance of separating the grain's starch, which is a valuable ingredient because it contains much resistant starch that can be used to create foods with a lower glycaemic impact (Ai *et al.* 2011; Wahjuningsih, Azkia and Anggraeni 2020). This is due to the fact that food products made with sorghum starch have a high dietary fibre content and slow-digestible starch qualities without compromising their sensory qualities (Cervini *et al.* 2021). Sorghum flour is frequently used to create new products. Still, research also highlights the importance of separating the grain's starch, which is a valuable ingredient because it contains much resistant starch that can be used to create foods with a lower glycaemic (Ai *et al.* 2011; Wahjuningsih, Azkia and Anggraeni 2020).

Research on sorghum grain extruded goods such as morning cereals and snacks, as well as extruded sorghum flour, utilised as a component in cakes, breads, and drinks, has increased. Better digestion of sorghum may result from using extruded flour rather than raw sorghum flour. Nonetheless, this procedure may decrease the concentration of some biocomponents relevant to human health (Jafari, Koocheki and Milani 2018; Yu *et al.* 2020). The extrusion method has an impact on the total phenolic content and total flavonoids of sorghum, which is linked to the loss of the phenolic components' biological activities (Xu, Wang and Zhao 2021).

2.8 Fermentation

Fermenting grains is one of the earliest processing methods, having been used by the ancient Egyptians to make bread and beer using lactic acid bacteria and yeasts (Hammes *et al.* 2005). The natural enzymes that hydrolyse the stored starch content are activated during fermentation (Nkhata *et al.* 2018). Sorghum has historically undergone spontaneous fermentation using the “back-slopping” method (Dlamini, Taylor and Rooney 2007) or by activating naturally present bacteria on the grain kernels (Taylor and Kruger 2019). In fermenting cereals, water is added to milled flour in 1:2–3 ratios, and the mixture is allowed to ferment at 25°C–37°C for 24–72 hours and up to 192 hours (Taylor and Kruger 2019).

Overall, fermenting sorghum improves its palatability, shelf life, and functioning while causing desired biochemical changes (Mohapatra *et al.* 2017; Mohapatra *et al.* 2019).

2.8.1 Natural fermentation

Natural fermentation, also known as spontaneous fermentation, has been occurring for decades. The sequential activity of several endogenous microorganisms existing in the substrate is typically used to accomplish this. Similarly, another method known as "back-slopping" involves adding a previously fermented product to a new lot to speed up the fermentation process and reduce the chance of fermentation failure (Galati *et al.* 2014). The multitude of microorganisms compete with one another during such spontaneous fermentation processes, and the microbiota is ultimately dominated by the best-adapted one, or ones. However, this leads to variances in the final product's sensory attributes, slower fermentation, reduced acidification, fermentation failure, the growth of unwanted pathogenic microbes, and the generation of unwanted products and metabolites (Galati *et al.* 2014). In order to guarantee consistency, maintain cleanliness, enhance quality, and assure continuous sensory quality and composition of fermented foods, a more controlled fermentation process is preferred, even if the majority of indigenous fermentation procedures still primarily rely on natural fermentation.

2.8.1.2 Production of ting and associated challenges

2.8.1.2.1 The production of ting

Porridges made from grains such as sorghum are a significant food item in Southern Africa (SSA), with thick and thin versions varying in flour/water ratios (Rosentrater and Evers 2018). Ting, sometimes referred to as *mabele, bogobe,* or *motogo*, is a traditional fermented sorghum porridge that is popular in South Africa, Botswana, and other Southern African countries. It has a unique sour flavour and is commonly eaten for breakfast, lunch, and dinner by people of all ages in underdeveloped countries (Adebo 2018). The endogenous microflora of sorghum, as well as microflora connected to the preparation tools and regional conditions, influence the traditional and natural spontaneous fermentation process used to make ting (Madoroba *et al.* 2011). Additionally, there are significant differences in the production of ting regarding taste, acceptability, and overall product quality (Mavhungu 2005).

Ting is made by combining sorghum flours with lukewarm water (1:1, w/v) in a container, and covering and incubating it for 1-3 days (Adebo *et al.* 2018). Alternatively, sorghum slurries can be inoculated using the “back-slopping” technique in previously used containers or with leftovers from prior

fermentation (Sekwati-Monang and Gänzle 2011). The soured slurry is then cooked in boiling water to make porridge from the ting.

A study conducted in the Gauteng province of South Africa examined ting samples from homes in Klipgat, Soshanguve, Tembisa, and Pretoria, with a focus on characterising the microbial flora responsible for the production of ting (Rapoo, Budeli and Thaoge 2023). The results showed that *Lactobacillus helveticus, Lactobacillus amylolyticus, Lacticaseibacillus paracasei, Lacticaseibacillus paracasei subsp paracasei, Lactiplantibacillus plantarum, Levilactobacillus brevis, Loigolactobacillus coryniformis and Loigolactobacillus coryniformis* were the common microorganisms present in ting (Rapoo, Budeli and Thaoge 2023).

2.8.1.2.2 Challenges associated with the production of ting

There are several difficulties in producing ting from spontaneously fermented sorghum, such as fluctuations in fermentation conditions that impact the end product's microbial interactions, composition, and safety (Madoroba *et al.* 2011). Hygiene is frequently overlooked in traditional settings where irregular fermentation temperatures and periods may be utilised. As a result, the fermentation processes become unpredictable and unrepeatable, producing goods with different textures, flavours, levels of sourness, and scents (Mavhungu 2005). Additionally, the nutritional composition, health-promoting qualities, and safety risks of ting are also affected. As a result, there is no standard scientific method for making ting; instead, an efficient method is required to guarantee the safety and health advantages of ting use.

2.8.2 Controlled fermentation

While it is impossible to overlook the significance and cultural benefits of spontaneous fermentation, using certain starter culture strains for fermentation is essential, particularly when exact sensory, nutritional, technical safety and other specialised criteria are sought. This has thus necessitated the selection and identification of specific strains (starter cultures) and the use of such organisms as starter cultures in a controlled fermentation process (Vinicius De Melo Pereira *et al.* 2020). Therefore, over the years, several studies have looked into the dominant strains in foods fermented with sorghum. These microorganisms were then isolated, purified, characterised, and preserved with the goal of using them to create final fermented products with the desired qualities ting (Madoroba *et al.* 2011).

2.8.3 Lactic Acid Bacteria (LAB) controlled fermentation

According to LeBlanc *et al.* (2013), LABs are bacteria that produce vitamins, making them a cost-effective and natural substitute for vitamin fortification. Additionally, the synthesis of acetate during LAB fermentation affects food quality, boosts antioxidant capacity, redox potential, and antibacterial qualities, and enhances the fermented product's flavour (Gänzle 2015). LAB are categorised as gram-positive microorganisms and are characterised by their rod- or coccus-shaped morphology, non-motility, non-spore-forming properties, and acid tolerance (de Oliveira *et al.* 2022). Their development depends on the accessibility of sugars, and they also require purines, pyrimidines, vitamins, and amino acids for metabolism (Collins *et al.* 2010; Mozzi *et al.* 2015). They are microaerophilic organisms. Lactic acid, carbon dioxide, and ethanol are among the end products that are produced when this kind of bacteria ferments carbohydrates (de Oliveira *et al.* 2022). Through exploitative competition, suppression of other microbes, and fast utilisation of carbohydrates and organic acid buildup, the majority of LABs control the microbiota of the majority of fermented foods (Gänzle 2015). Lactate is the main by-product of metabolism when fermentable carbohydrates are plentiful. Additionally, LABs' proteolytic activity enables them to break down proteins and peptides, producing metabolites that enhance the flavour, texture, structure, and antibacterial action of certain foods (Gänzle 2015).

LABs have been used for decades in the preparation of fermented meals and are known to improve the final composition of foods (Soro-Yao *et al.* 2014). Regarding their usage as dietary supplements and as starter and/or protective cultures, they are classified generally as safe (GRAS) and have a qualified presumption of safety (QPS) (Collins *et al.* 2010). Their production of a wide range of metabolites, such as ethanol, acetic acid, aromatic compounds, several enzymes, and bacteriocins, makes them technologically intriguing (Todorov and Holzapfel 2015; Adebo 2018). By lowering pH and producing acetic, propionic, and lactic acid as by-products, lactic acid bacteria also help to ensure the safety of food by subsequently inhibiting the growth of other harmful microorganisms (Leroy and De Vuyst 2004; Gänzle 2015; Russo, Spano and Capozzi 2017)

It has been documented that the subsequent use of LABs during sorghum fermentation increases acidity, speeds up the fermentation process, enhances functionality and nutritional quality, and contains components that promote health (Svensson *et al.* 2010; Sekwati-Monang and Gänzle 2011; Ray and Joshi 2014)). The quality of fermented sorghum products, such as Ting, can be improved by using these LAB starter cultures, which offer nutritional, technical, and health benefits, making Ting a nutritious and tasty porridge option.

2.8.3.1 Starter culture

According to Vinicius De Melo Pereira *et al.* (2020), starter cultures are specific microbial preparations that boost the fermentation processes' effectiveness. The use of starter cultures for a more regulated fermentation process has resulted from advancements in fermentation technology and the growing demand for fermented goods of higher and consistent quality (Adebo 2018). Numerous food industries use starter cultures, including the dairy industry for the production of cheese, yoghurt, and other fermented dairy products; the meat industry, primarily for the production of sausages; and the alcohol and wine industries. They are also used in the production of vinegar, the preparation of rice and soy-based oriental products, baking, the fermentation of cereals, and the production of fermented fruits and vegetables (Speranza *et al.* 2017).

The microorganisms chosen for starter cultures are isolated from the native microbiota of traditional products because they can control food spoilage and pathogenic microbiota (Laranjo, Potes and Elias 2019), are well suited to the environmental conditions of food processing, and impart a particular appearance, texture, aroma, and flavour characteristics (García-Díez and Saraiva 2021). A thorough investigation of the metabolism and activities of the microbe or microorganisms must be conducted before choosing them as a starter, or starter culture since, in some situations, their impacts and/or characteristics may differ between food items and laboratory settings. Additionally, it must be acknowledged that the starter culture is safe, scalable, and stable throughout storage (Taskila 2017). Yeast, moulds, and bacteria are microorganisms that are utilised as starter cultures (Laranjo, Potes and Elias 2019). The most prominent category of bacteria is called LAB, and it is utilised in the fermentation processes of meat and dairy products (Zdolec, Mikuš and Kiš 2022). Additionally, the production of traditional beef sausages has included mixed starters that comprise Lactobacillus species, gram-positive catalase-positive cocci, and yeasts (Laranjo, Potes and Elias 2019). The primary application of yeasts is in the fermentation of alcoholic drinks, the most common being the manufacture of wine and beer (Maicas 2020). In terms of starter moulds, they are utilised to produce cheeses, meat products, fermented vegetable goods and soy-based products (Chen *et al.* 2022).

2.8.4 Effect of fermentation on sorghum

In sorghum, fermentation has a significant impact on the biochemical makeup. Through the fermentation of extracellular enzymes that break down the stored starch that is enmeshed in a protein matrix, LAB fermentation has been demonstrated to reduce the amount of fat and carbohydrates, primarily through respiration (Mohapatra *et al.* 2017). According to a study by Mohapatra *et al.* (2019), fermentation

treatment of sorghum reduced its fat level from 4.7% to 3.6% while increasing its protein content. Conversely, the hydrolysis of stored proteins in fermented sorghum improves the digestibility of lysine and protein (Adeyanju *et al.* 2019). By complexing stored proteins, fermentation breaks down tannins and phytates, improving digestibility and lowering baking challenges related to sorghum dough (Mohapatra *et al.* 2017). In diabetics, dietary fibre is a crucial component of the glycaemic index, and it's generally accepted that fermentation increases its concentration (Ding 2024). Research has indicated that xylanase breakdown results in either a 12% decrease in total dietary fibre or no change at all (Taylor and Kruger 2019). There is no net change in the mineral concentration since fermentation cannot destroy or synthesise them. The majority of minerals combine with anti-nutrients such as phytates, which reduces their bioavailability (Adeyanju *et al.* 2019). According to Mohapatra *et al.* (2019), the leaching of water-soluble minerals into the fermentation media is the cause of the loss of mineral content.

Sorghum is well known for a variety of bioactive qualities (Awika and Rooney 2004), which have been connected epidemiologically to lower risks of certain illnesses (Duodu and Awika 2019). Sorghum's total phenolic acid, tannin, and phytate concentrations have been demonstrated to decrease with lactic acid fermentation (Mohapatra *et al.* 2019). These observations are consistent with those made by Mohapatra *et al.* (2019), who found that fermenting sorghum flour reduces the amount of total phenolics. A 49–68% decrease in tannins was noted by Dlamini, Taylor and Rooney (2007) in fermented sorghum porridge. Lactic acid fermentation lowers sorghum tannin levels, reducing their bio-accessibility and inhibiting the absorption of essential minerals such as iron and zinc (Adeyanju *et al.* 2019). This process makes sorghum more bioavailable, resulting in a more nutritious porridge (Adeyanju *et al.* 2019). In addition, fermentation acts as a barrier against enteropathogenic bacteria by producing bacteriocins, ethanol, and organic acids, which lower the pH, inhibiting their growth. This lower pH indicates successful fermentation, while by-products suppress enteropathogenic bacteria, which can be harmful to human health (Mohapatra *et al.* 2017).

2.9 Product development

Food product development is a constantly growing list of research activities that include issues related to the main product itself as well as issues with raw materials, quality control, packaging, technical aspects of production, nutritional value labelling, necessary technology, and marketing (Joseph and Sharma 2022). The food product development process is a systematic collection of research efforts aimed at creating a particular project and product design programmes (Earle and Earle 2007).

There are several reasons why businesses create new products (Alam 2022). According to Joseph and Sharma (2022) companies produce new products to increase profitability and to ensure continued growth of the company. According to (Alam 2022), businesses create innovative products to keep one step ahead of their rivals. Furthermore, businesses might obtain a competitive edge by creating innovative products (Alam 2022).

2.9.1 Food product development stages

Gilbert and Prusa (2021) advise developing new products using the stage and gate strategy. The stage and gate system has the following stages: ideation, formulation, processing and commercialisation, which are depicted in a process in Figure 2.7. The Stage-Gate process consists of several phases of development, each followed by a gate where deliverables and advancement criteria make decisions. It has been applied with success in several sectors, increasing cycle times and improving product success rates (Cooper 2022).

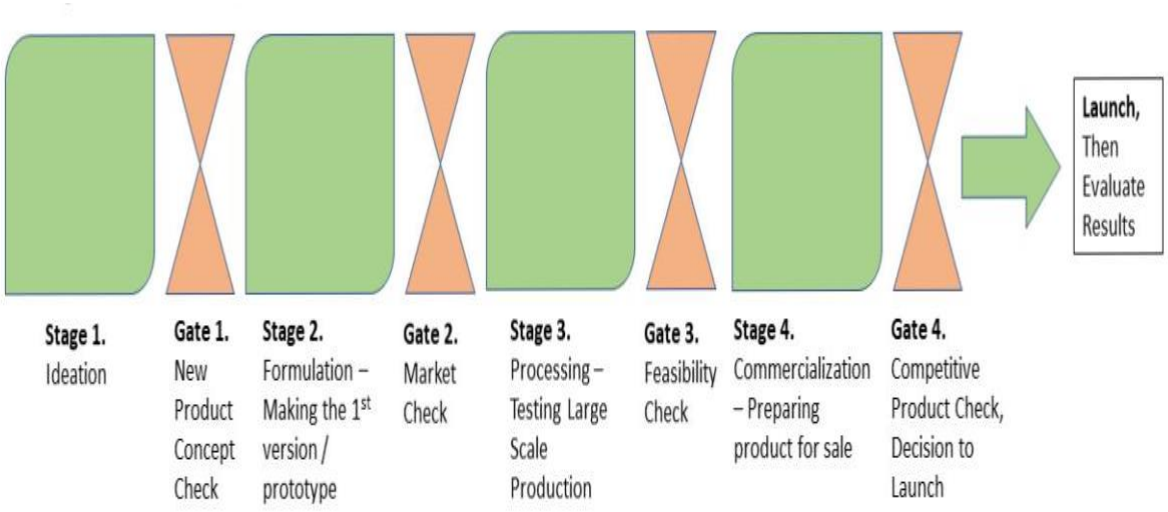


Figure 2. 7: Stage & Gate system for the development of new products (Gilbert and Prusa 2021)

The process of product creation begins with identifying market gaps and generating multiple ideas to meet consumer needs. Some ideas may be discarded if the product concept already exists or if materials or processes are too expensive. The top three to five ideas may proceed to the formulation phase, where the product is manufactured on a small scale and consumer testing is conducted. The second checkpoint determines which product has sufficient consumer interest (Gilbert and Prusa 2021).

During the processing phase, two to three products are upgraded using more extensive equipment to

determine manufacturing costs and efficiency. Food safety and quality testing is carried out to ensure a safe and consistent product. Shelf-life testing is performed to ensure the product maintains acceptable quality for a sufficient duration (Gilbert and Prusa 2021).

The commercialisation stage focuses on getting the product ready for sale in grocery stores, including final pricing, consumer sensory evaluation, and package design. The final gate confirms that all mistakes and significant flaws have been resolved. Following the product launch, factors like increased interest, sales, market domination, and total corporate revenue from sales are used to evaluate its effectiveness. Gilbert and Prusa (2021) highlight that each company may employ its unique method for navigating the phases of product creation, which can vary based on resources, timeframes, and the category of products under development.

2.10 The science of food sensory assessment

2.10.1 Introduction to food sensory assessment

Quality is the ultimate indicator of a food product's desirability and can be evaluated objectively and through sensory approaches. Organoleptic evaluation, often known as sensory assessment, uses human senses to assess the quality of food. Every time food is consumed, a decision is made based on sensory quality, which includes a variety of impressions that affect food acceptance, such as look, flavour, and mouthfeel (Zhang *et al.* 2003). According to Rodrigues, Dias and Teixeira (2024), sensory qualities are subjective reactions driven by social and psychological variables rather than intrinsic food properties. These elements ultimately determine food acceptance and preferences. In addition to addressing subjective preferences, sensory assessment is a scientific field that measures, analyses, and interprets physiological and psychological reactions to physical stimuli, as well as how people react to food and beverages (Mihafu, Issa and Kamiyango 2020).

2.10.2 The role of taste, smell, sight, touch and hearing in sensory assessment

Sensory assessment is a process that utilizes the five main human senses: taste, smell, sight, touch, and hearing (Stone and Sidel 2004). Taste detects basic tastes like sweet, salty, sour, bitter, and umami, while smell helps consumers perceive flavors by detecting volatile molecules in food (Rodrigues, Dias and Teixeira 2024). Taste perception is crucial for evaluating food products' intensity and palatability. Trained panellists use sensory evaluation techniques to measure flavor attributes and detect subtle differences (Lawless and Heymann 2010). Prescott (2012) states that aroma is essential for eliciting sensory assessment and influencing flavor perception. Techniques like aroma intensity scaling and profiling quantify and characterize food products' olfactory qualities (Pop 2023). A food's overall flavour is a combination of its scent and flavour (Ruiz-Capillas and Herrero 2021).

Sight is another crucial sense that is used in sensory evaluation since visual cues provide crucial information about the form, colour, and look of food products. The brain and eyes use electromagnetic waves in the visible light spectrum to process images. The assessment of product quality, freshness, and aesthetic appeal is aided by visual examination, which shapes consumer expectations and purchase decisions (Spence 2015).

Taste is also crucial in sensory assessment, particularly when assessing textural qualities such as hardness, chewiness, and mouthfeel. Perceptions of texture correlate with quality and satisfaction, and customers' acceptance and choice of items are influenced by their perceptions of texture (Stieger and Kremer 2019). Hearing indirectly influences perception, as the ear and brain detect sound through vibrations (Pop 2023). Auditory signals, such as crunchiness, hardness, chewiness, and sizzling, can influence perceived freshness and quality, improving the whole sensory experience (Zampini and Spence 2004).

2.10.3 The significance of food sensory assessment in the food industry

The food industry highly values sensory assessment (Rodrigues, Dias and Teixeira 2024). According to Stone, Bleibaum and Thomas (2020), sensory analysis is a scientific specialisation that measures, examines and explains how panellists' senses of sight, smell, taste, touch, and hearing respond to the unique characteristics of food. This process is essential for identifying consumer preferences and ensuring that foods meet the desired standards of quality

and palatability (Tzia *et al.* 2023). The two main categories of traditional sensory analysis are analytical and affective (refer to Table 2.1) (Ruiz-Capillas and Herrero 2021). Analytical tests, which include descriptive and discriminatory evaluations, aim to characterise and distinguish the products (Lawless and Heymann 2010), while affective tests, which are further subdivided into preference and hedonic tests (Stone, Bleibaum and Thomas 2020), attempt to assess the product's level of acceptance.

Table 2. 1: Different traditional and novel sensory tests used to evaluate food

Sensory tests	Types	Subtypes	Panellists	Question?
Analytical	Discrimination	Duo-trio Triangle Projective mapping Napping	Trained or Consumers	Are the new products different?
	Descriptive	Flavour profile Texture profile Quantitative Descriptive Analysis Free choice profiling Flash descriptive analysis Spectrum Check-all-that-apply Flash profile Rate-all-that-apply	Greater training/ Semi-trained/ Consumers	How are the new products different?
Affective	Preferences/ choice	Pair-comparative Polarized sensory positioning	Naive	Which sample do you prefer?
	Hedonic		Naive	How do you like the sample?

2.10.4 The value of sensory assessment in the creation of child-centred food products

The hedonic scale, which gauges how much a consumer likes, or prefers a product, is one popular technique in sensory evaluation (Schluterman *et al.* 2024). The facial hedonic scale, in

particular, is an intuitive and effective tool for children and adolescents, allowing them to express their preferences through visual cues (Popper and Kroll 2011). According to Meilgaard, Carr and Civille (1999), children between the ages of 6 and 13 or 14 years are better suited for lower hedonic scales that use pictures since they are much simpler to comprehend and explain. According to Lawless and Heymann (2010), the smiley face hedonic scale is based on the notion that youngsters find the drawings amusing and draw their attention to the job at hand.

The seven-point hedonic scale contains descriptive negative and positive levels ranging from 1='super bad' and 7='super good', providing a spectrum that accommodates nuanced emotional responses to food (Stone, Bleibaum and Thomas 2020). Kimmel, Sigman-Grant and Guinard (1994) assessed the applicability of preference ranking, hedonic scaling, and the paired preference test with children aged 2 to 10 years. The findings demonstrated that toddlers as young as four could utilise a seven-point hedonic scale, and children older than two could consistently complete a paired-preference test. Additionally, Chen, Resurreccion and Paguio (1996) discovered that toddlers aged 3–6 could use 3-, 5-, or 7-point hedonic scales—which were similarly anchored with the terms 'super-bad' and 'super-good'—to indicate how much they liked food items. By employing a 7-point facial hedonic scale, researchers can note even slight differences in how children perceive food products, thus they are valuable in assessing acceptability among students.

The use of sensory evaluations in the development process of breakfast cereals is of high importance as the consumption of breakfast influences the nutritional well-being of children and adolescents, note Gibson-Moore, Spiro and Stanner (2023). Hallström *et al.* (2011) state that breakfast cereals are one of the first meals a child eats in a day, and the palatability of the breakfast cereal can have significant implications on consumption patterns. Sensory evaluation is a critical strategic factor within a product development system to ensure that the final products appeal to the consumers' preferred tastes and choices (Świąder and Marczewska 2021).

2.10.5 The value of sensory assessment in school feeding programmes

Sensory evaluation can be used to create nutritious meals for schools, ensuring that recipes cater to children's taste preferences while also being financially viable for the school feeding programme (Cox *et al.* 2021). A systematic review revealed that numerous studies utilized various approaches for sensory evaluation and acceptance of school menus within school

feeding programs (SFP) across 13 countries (Santana *et al*. 2023). Brazil, South Korea, and the United States were the nations that most often explored this topic, likely due to their extensive and long-established SFPs (Santana *et al.* 2023).

In Brazil, it is mandatory to assess the acceptability of school meals in public schools (Gomes 2011). The meal most frequently evaluated was lunch, as the majority of students attend school throughout the day and dedicate both morning and afternoon to their studies (Santana et al. 2023). Additionally, the primary school level was the most commonly evaluated educational stage (Santana *et al.* 2023). Among the 13 countries examined, around 70% of the research utilized either the hedonic scale, with the 5-point scale being the most widely used (Santana *et al*. 2023). Studies from Italy (37.50%), the Philippines (100%), and Finland (100%) predominantly employed the 7-point scale (Santana *et al.* 2023).

In a study conducted in South Africa, Hassanally (2020) used a 7-point facial hedonic scale to perform sensory evaluations with primary school students while developing an energy-dense biscuit intended for the NSNP. The sensory analysis was carried out first with study staff and subsequently with the students to assess acceptability (Hassanally *et al*. 2021). Likewise, Kearney *et al*. (2011) employed a hedonic scale in their development and processing of vetkoek (a type of fried bread) for a school feeding initiative in South Africa; however, they did not specify the exact type of hedonic scale used. As part of the product development, a paired preference test was done to identify the most preferred option among three vetkoeks among primary school students (Kearney *et al*. 2011).

Incorporating sensory evaluation into SFP is crucial for determining the quality of the services offered, particularly in relation to school meal provision (Rigon *et al.* 2022). By priorotizing the sensory appeal of the SFP menu, stakeholders can enhance student participation in SFP and minimize food waste, thereby aiding sustainability (Santana *et al.* 2023).

2.11 Conclusion

Investigating sorghum, pearl millet and the most recent processing methods, such as fermentation, demonstrate that incorporating these indigenous grains might enhance the nutritional value and dietary variety of the NSNP. The study's context and applicability are further improved by knowledge gained from practices in school nutrition programmes globally.

Ultimately, a strategy is described that has to be employed to bring nutrient-dense and locally sourced foods to school meal programmes, which in turn is cause for increased sustainability

and health among students. With the findings presented in this study, the study could make a significant contribution to the sustained efforts in improving food and nutrition outcomes under the NSNP for the realisation of healthy and productive generations in the future.

The literature review highlights gaps in understanding consumer acceptance, particularly among children, of new products like instant breakfast cereals incorporating indigenous grains. The current NSNP and comparable programmes globally lack comprehensive nutritional assessments, particularly regarding the adequacy and variety of essential nutrients provided to students. Furthermore, the literature review acknowledges the significance of food items in school meal programs, but lacks a comprehensive understanding of cultural preferences and dietary restrictions in South Africa or how these factors affect the acceptance and effectiveness of the NSNP and similar programmes globally The literature review highlights gaps in understanding the impact of different fermentation methods on the palatability of sorghum among school-aged children, indicating potential for innovation in food processing for school feeding. Additionally, there is a lack of longitudinal studies on the long-term health and educational impacts of NSNP, suggesting the need for research on sustained changes beyond immediate nutritional benefits.

CHAPTER 3: RESEARCH DESIGN AND METHODOLOGY

3.1 Introduction

This chapter provides a detailed description of the research approach and methodology utilised in this product development study. The study's setting, design, sample selection, inclusion and exclusion criteria will all be thoroughly discussed. Additionally, the chapter provides an in-depth discussion of the measurement tools, data collection methods, and data analysis procedures. Ethical considerations, along with the study's reliability and validity, are also thoroughly addressed.

3.2 Setting

The study was conducted in the KZN province's iLembe district, situated on the eastern coast between King Cetshwayo District in the north and eThekwini Metro in the south. To the west, iLembe is bordered by the districts of uMgungundlovu and uMzinyathi (Treasury 2022). Compared to the other nine KZN District Municipalities, this district has the least land area, with only about 32 609 km² of land area and approximately 782 661 residents, according to the Department of Economic Development, Tourism and Environmental Affairs (DEDEAT 2021). Mandeni, KwaDukuza, Maphumulo, and Ndwedwe are the four local municipalities that make up the iLembe district, as seen in Figure 3.1.

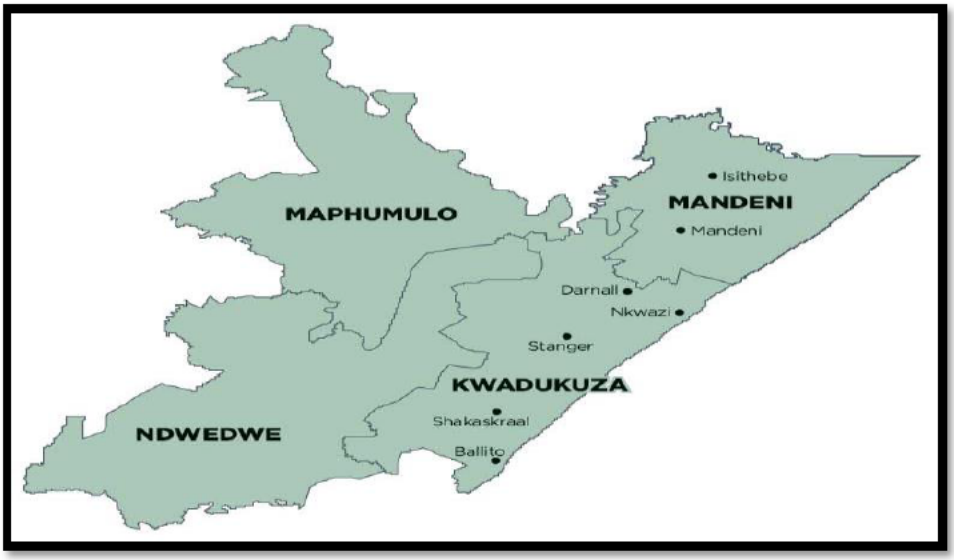


Figure 3. 1: North coast map of KwaZulu-Natal's iLembe district, displaying local municipalities (Municipalities of South Africa, 2024)

3.3 Research design

Quantitative research, according to Creswell (2003), is the process of gathering data, quantifying it, and then analysing it statistically to support knowledge claims. Questionnaires are frequently used to collect information for quantitative research studies, often administered in the form of surveys (Hair *et al.* 2017). In this study, information on the learners' breakfast needs and preferences and the sensory acceptability of the developed breakfast was gathered using face-to-face questionnaires. Face-to-face surveys offer several benefits, including improved data quality and a reduced non-response rate, as participants can seek clarification from interviewers on unclear questions (Cohen, Manion and Morrison 2002).

An instant breakfast cereal suitable for the NSNP was developed from millet and sorghum. Prior to the study's product development phase, a cross-sectional quantitative breakfast needs assessment and preference survey was conducted among school learners to inform the product development process. During the product development process, sensory assessment was conducted among DUT students (refer to ethical considerations) who were frequent consumers of instant breakfast porridge during each product development trial to improve the quality and acceptability of the product. This was followed by a quantitative sensory assessment of the product among learners.

3.4 Study population and sampling

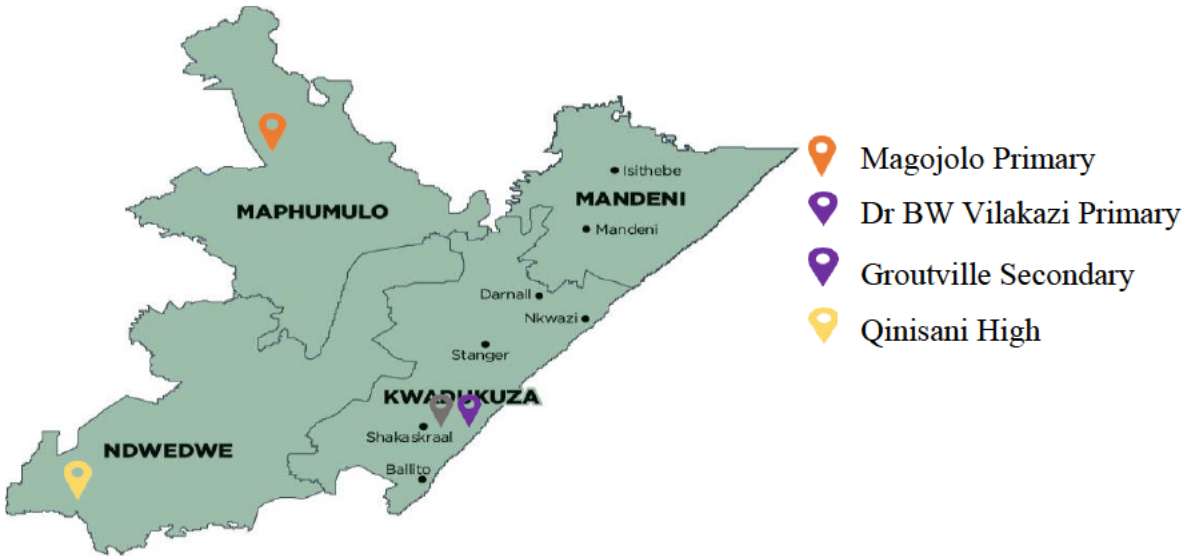


Figure 3. 2: Location of schools in the various municipalities in the iLembe district, KZN

Learners from four NSNP-participating schools in KZN, iLembe district, namely Magojolo Primary, Dr. BW Vilakazi Primary, Qinisani High, and Groutville Secondary schools aged

seven to 20 made up the research population. Figure 3.2 shows the locations of the selected schools on the map of the iLembe district in KZN. Magojolo Primary, a quintile one school with 205 learners, is located in a rural location. Similarly, Qinisani Secondary is a quintile two school and is situated in a rural area. Located in a peri-urban setting, Dr. BW Vilakazi Primary is a quintile three school, with 1 700 learners enrolled at the school. Groutville Secondary is another quintile three school located in a peri-urban area with a much larger enrolment of 2 959 learners. Therefore, the selected schools can be characterised as having a balance in terms of the study area's demography; the schools are located in both rural and peri-urban areas, and they encompass all the nuances of the different socioeconomic statuses.

Furthermore, these schools were specifically chosen because they were the pilot schools for the United Nations Children's Fund (UNICEF) study titled 'Modelling of the Blueprint for Improving the South African School Food Environment', a stakeholder-informed intervention pilot study to improve the school food environment in South Africa. These stakeholders can influence behaviour change since they are directly or indirectly involved in the school food environment (Pal *et al.* 2024). This is crucial to improve the learning outcomes, general health, and nutritional status of South African school learners.

Currently, the NSNP provides meals to over nine million children every school day in South Africa (Department of Basic Education 2022). According to Taherdoost (2017), for any population exceeding one million, a sample size of 384 achieves a 95% confidence level with a 5% margin of error. For the breakfast need assessment and preference survey, the sample size was established at 405. A larger sample of participants (at least 50 or more) yields more accurate results and a better understanding of consumer attitudes (Zoecklein 2012). It has been reported that sample sizes of at least 40-50 participants can produce stable averages for sensory attributes Moskowitz (1997); Gacula Jr and Rutenbeck (2006). Therefore, the sensory assessment included a sample of 200 learners, 50 from each school and from classes that took part in the need assessment and preference survey. By splitting the participants into different grade levels, stratified random selection was used to obtain a representative sample from the target population (Joubert *et al.* 2007). More precisely, the population was separated into two strata according to school type and educational level: primary (grades 4 to 7) and secondary (grades 8 to 12) schools. Learners were selected randomly across each stratum to have an equal distribution of learners from each grade level. This method enhanced the reliability of the sensory assessment results by allowing the sensory assessment to cover all grades and school learners.

Additionally, eight consenting students aged 18-30 years from the Department of Food and Nutrition at the DUT who were experienced in sensory assessment were used in the product development trials to describe and critically analyse the sensory attributes of the breakfast cereal to inform changes for the following trials. The study was separated into phases to establish a coherent progression of the research (Figure 3.3).

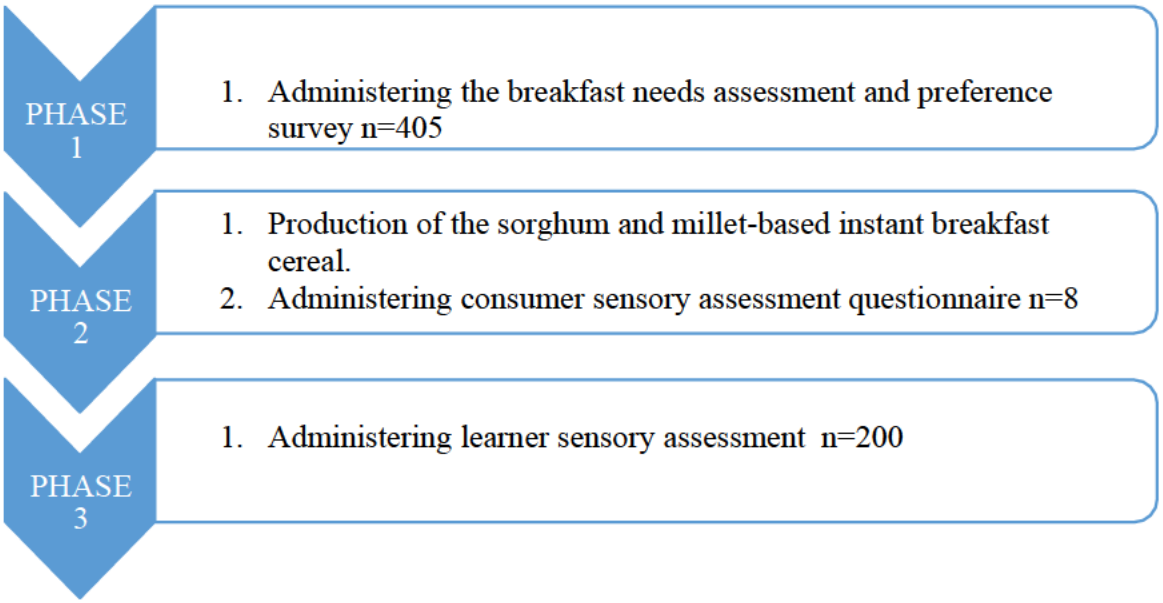


Figure 3. 3: Flow diagram showing the phases of the research process

3.5 Inclusion and exclusion criteria

3.5.1 Breakfast needs assessment and preference survey

3.5.1.1 Requirements for inclusion:

- Learners from NSNP provisioning schools in the iLembe district.
- Learners aged 7 to 20 years, including both boys and girls.
- All racial groups.
- Disabled and non-disabled learners.

3.5.1.2 Requirements for exclusion:

- Learners that were not attending the NSNP provisioning schools in the iLembe learners above 20 years old.
- All school employees.

3.5.2 Sensory assessment during product development trials

3.5.2.1 Requirements for inclusion:

- DUT registered students who were knowledgeable about sensory assessment.
- Male and female students who were 18 to 30 years old.
- All racial groups.
- Disabled and non-disabled students.

3.5.2.2 Requirements for exclusion:

- Students unfamiliar with sensory assessment and who were not registered at DUT
- Students who were >30 years.
- Students with dietary sensitivities.
- Students who smoked.
- Students who were pregnant.

3.5.3 Sensory assessment for learner acceptability

3.5.3.1 Requirements for inclusion:

- Learners from NSNP-provisioning schools in the iLembe district that were included in the UNICEF pilot study.
- Learners aged 7 to 20 years, including both boys and girls.
- All racial groups.
- Disabled and non-disabled learners

3.5.3.2 Requirements for exclusion:

- Learners attending the schools selected to participate in the study in the iLembe district who did not partake in NSNP.
- Male and female learners above the age of 20 years.
- Learners with dietary sensitivities.
- All school employees.

3.6 Measurement tools

3.6.1 Phase 1:

3.6.1.1 Breakfast needs assessment and preference survey questionnaire

A breakfast needs and preference assessment was conducted to ascertain the school learners' consumption and preferences for breakfast as the morning meal before classes. The student

collaborated with the supervisors to create the breakfast needs assessment and preference questionnaire. The questions were designed to collect information regarding the learners' breakfast preferences to develop an appropriate breakfast cereal produced from sorghum and millet. The questionnaire was piloted among ten learners with a similar profile to the target audience to ensure comprehension. The survey was translated to isiZulu and back-translated into English for analysis and interpretation.

The survey combined open-ended and closed questions (multiple choice and yes/no) to collect the learners' demographic information, breakfast consumption habits, and preferences (refer to Appendix A). The response options were simplified to make it easy for the learners to understand and select them. The logical order of the questions, which began with demographic data and progressed to more detailed eating habits and preferences, including questions regarding food security, also made it easy for learners to follow. Breakfast options listed in the questionnaire included instant porridge, rolled oats (Jungle oats), extruded cereals (Weet-Bix, Kellogg's Corn Flakes and All Bran Flakes), Future Life and ProNutro. Flavour choices included vanilla, banana, strawberry, chocolate, and options with no flavour.

The questionnaire was piloted among learners who were excluded from participating in the main study. The primary goal of the piloting was to ensure that the research tool was error-free, clear, and unambiguous. Piloting also ensures that the tool is constructed correctly. This step allows the researcher to find and eliminate queries that aren't relevant to the study (Kimmie 2007). Table 3.1 provides specifics on modifications made based on the feedback and replies from the pilot study on the breakfast needs assessment survey.

Table 3. 1**:** Pilot study modifications.

Question number	**Original Question**	**Revised Question**
2	Please state your gender: Male | Female	Please state your gender: Boy | Girl
11	Which breakfast cereal do you prefer from the list below? o Instant porridge o Rolled oats	Which breakfast cereal do you prefer from the list below? o Instant porridge o Jungle oats

	o Weet-bix, Kelloggs corn flakes, All bran flakes o Future life, Pronutro o Other, specify _____	o Weet-bix, Kelloggs corn flakes, All bran flakes o Future life, Pronutro o Other, specify _____

Three changes were made to reduce confusion among school learners. Clearer wording was used to replace two of the questions.

Stratified random sampling was applied to select a sample of learners from four of the NSNP-receiving schools (two primary and two high schools) with a total of 405 participants. After determining the total sample size, proportional allocation was applied based on the number of learners in each school. Participants were randomly selected from each school to ensure representation across all grades and school types, providing a diverse and accurate sample for analysis. A gatekeeper's permission letter was sought and obtained from the Department of Basic Education before the schools were visited (refer to Appendix B and Appendix C). Each school's principal was contacted to obtain permission to perform the study. Each learner received a letter of information outlining the goals, objectives, procedures, and advantages, which were presented both orally and in writing (refer to Appendix D). Thereafter, letters of information (refer to Appendix E) and consent forms (refer to Appendix F) were sent to parents via the designated teacher. Learners who obtained their parent's consent gave their permission (refer to Appendix G) to participate in the study. Once consent and assent were granted, the breakfast needs assessment and preference survey were conducted.

The principal of each school introduced the researcher, assistants and supervisors to the school community upon their visit to Magojolo Primary, Dr BW Vilakazi Primary, Qinisani High, and Groutville Secondary schools. To ensure thorough comprehension, the learners were given a simplified presentation of the study topic, reading material, and an explanation of the survey questions. The learners were then asked to complete the survey truthfully and not engage with each other whilst answering. The questionnaires were collected and counted at the end of the survey. An Excel spreadsheet was used to record the results of the breakfast needs and preference survey. The results were then analysed to determine the most suitable breakfast cereal for development. The next step was to start the product development process.

3.6.2 Phase 2

3.6.2.1 Product development of a sorghum and pearl millet-based instant porridge

The second phase involved developing a sensory-acceptable sorghum and millet-based instant breakfast porridge. The most popular breakfast cereals were determined by analysing the breakfast needs assessment and preference survey findings. According to the breakfast needs assessment and preference survey findings, instant porridge was the most practical breakfast cereal. Three trials were carried out using various compositions of ingredients. The researcher conducted all of the product development trials under supervision at the food science laboratory and enzyme laboratory of the DUT Department of Food Science and Biotechnology. The ingredients were sourced at a local retail store.

To develop the sorghum and pearl millet-based instant porridge, the sorghum grains were fermented; this process was essential in developing the instant porridge. The isolation and preparation of the starter culture and the fermentation process were conducted at the enzyme laboratory of the Department of Biotechnology and Food Science at the DUT under the supervision of a Biotechnology master student.

3.6.2.2 Isolation of starter culture

Sorghum grains were ground with a hammer mill fitted with a sieve with a screen mesh size of *1 mm*. The sorghum was then fermented to screen for the dominant strain. The fermentation was carried out with 1:3 sorghum to water (w/v), where the distilled water and flask were sterilised. The sorghum mixture was incubated for 24 hours at 37℃. Ten-fold serial dilutions of the fermented sorghum were carried out using sterile normal saline up to the 10-9 dilution. A nutrient agar plate was spread-plated with 0.1 ml of the suitable dilution. The plate was incubated at 37℃ overnight. After incubation, a single colony was subcultured in a nutrient agar through a four-way streak to obtain pour culture. The culture was incubated overnight and used to prepare the starter culture.

3.6.2.3 Optimisation of starter culture

Aqueous suspensions of starter culture were prepared from the above 24-hour culture on nutrient agar plates. The overnight culture was transferred to the nutrient broth with sterile loops and incubated at 37℃. To optimise incubation time for the fermentation, a small fermentation was conducted, and samples were collected every three hours until the ideal pH for fermentation was obtained. All the ingredients and equipment were autoclaved for the fermentation, and the sorghum and water ratios were 1: 3. After mixing all the ingredients, 10%

of the overnight culture was inoculated and incubated at 37℃. The culture was then used to monitor the pH until the fermentation reached the ideal pH. For this process, all equipment was autoclaved, and samples for pH were collected every three hours under sterile conditions until the ideal pH (level) was obtained.

3.6.2.3 Fermentation of sorghum grain

For the main fermentation, the ground sorghum, the distilled water, and the flasks were autoclaved at 121°C for 15 minutes. The autoclaved sorghum was mixed with sterile distilled water (1:3) in a flask. The sorghum mixture was then inoculated with 10% of the starter culture and incubated at 37°C for the incubation time, which was determined above. Figure 3.4 illustrates the fermentation process that was utilised. After this, sodium benzoate was added to stop the fermentation process, and the fermented sorghum was subsequently used to prepare the instant breakfast cereal.

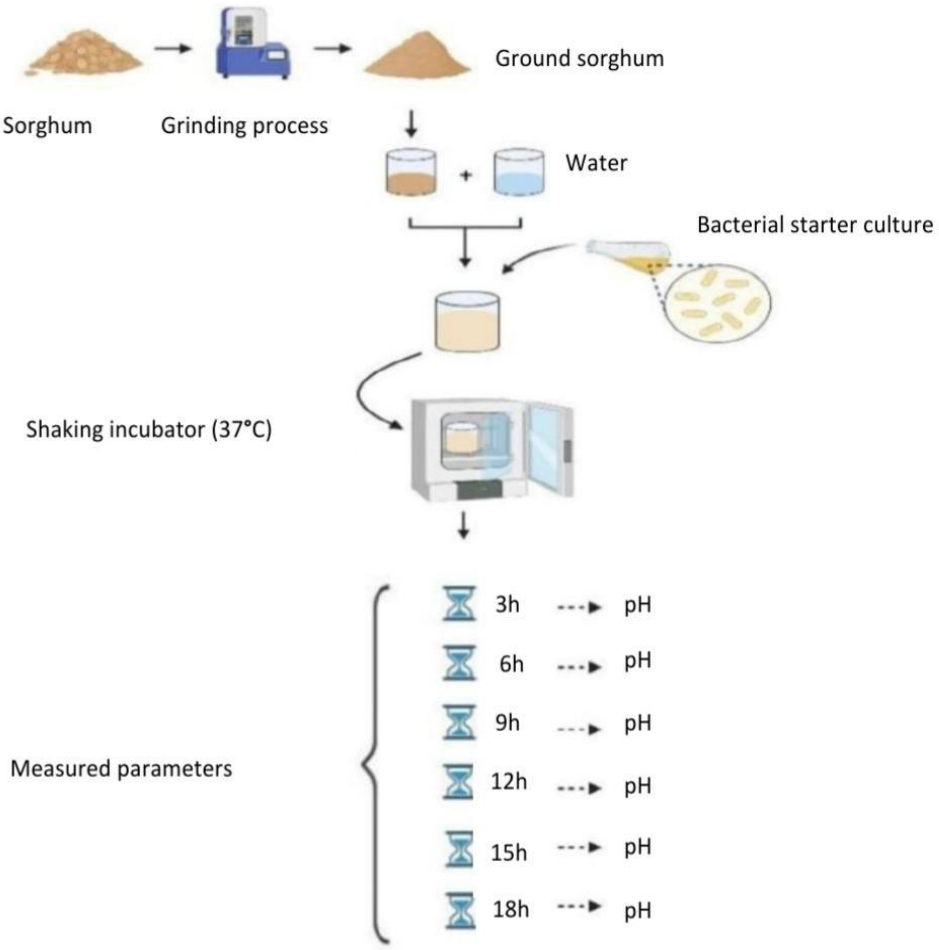


Figure 3. 4: Experimental design for the fermentation process of sorghum (Figure was adapted from Osman *et al.* (2022)).

3.6.2.4 Preparation of instant porridge powder

A 1:1 ratio of fermented sorghum flour and pearl millet flour was cooked in sterilised distilled water to prepare the instant porridge. Water helps to regulate the cooking temperature and the consistency of the porridge and acts as a medium by carrying flavours (Donmez *et al.* 2021). Whole-milk powder was added to enhance the protein content and micronutrient quality of the instant porridge (Tumwine *et al.* 2019). Moreover, soya-based fat powder was used to improve the mouthfeel of the formulation (Mu *et al.* 2022). According to the breakfast needs assessment and preference survey findings, chocolate was the most preferred breakfast cereal flavour among the school learners; therefore, cocoa powder was added to give the formulation a chocolate flavour and taste (Aribah *et al.* 2020). Salt, which is a food preservative that is also used as a flavouring agent, was added to enhance the flavour, texture, and colour of the porridge (Sun *et al.* 2021). Furthermore, brown sugar was added as a natural sweetener to add extra flavour and retain moisture well due to its high hygroscopic properties (Brown, Walter and Beathard 2018). Towards the end of the cooking process, the flavour of the porridge was further enhanced by adding vanilla essence (Kapoor 2021) The porridge was then cooked in a saucepan until it reached the desired consistency.

Following the cooking process, the porridge was dried in an oven that was set to a controlled temperature of 60°C. The reason for using this temperature was to increase the product's shelf life by minimising nutrient loss and efficiently lowering the moisture content to prevent microbial development. Once the porridge was dried, a hammer mill was used to grind the dehydrated porridge into a fine flour. To ensure that the final product would be free-flowing and not form lumps, silica dioxide was added as an anti-caking agent. Silica dioxide ensures that the free-flowing properties of the instant porridge are maintained (Shankar *et al.* 2024). Finally, the finished product was packed in airtight, moisture-proof polyethylene packets to improve further shelf stability and guard against environmental elements that might degrade quality. A ratio of 1: 1.7 (porridge: warm water) was used to reconstitute the instant powder into a porridge before serving.

3.6.2.5 Quality control

The raw materials used in the formulation of the sorghum and pearl millet instant porridge were sourced in a manner that ensured that they were of the highest quality and safety. For instance, all the raw materials used in this experiment were purchased from different, reliable local sources that meet high-quality standards. Furthermore, the suppliers were identified based on their ability to deliver quality products with appropriate food safety compliance, meaning that

the ingredients were checked for different parameters, such as physical contaminants and their maximum admissible limits for food production. In addition, the ingredients underwent visual inspection to confirm their quality before they were used to prepare healthy and safe porridge for learners in school.

The sorghum and pearl millet-based instant porridge was prepared in a well-ventilated food preparation laboratory. The researcher utilised a cleaning checklist (refer to Appendix H) to limit the risk of contamination and guarantee that good hygiene standards were maintained throughout the production process. The laboratory was free of pests, and no other food was prepared during the instant porridge production periods. The porridge was produced using good hygiene practices (GHP), which included frequent disinfection and cleaning of work surfaces, equipment, and utensils. Personal hygiene measures were also observed, such as hair covering and frequent hand washing.

According to Malik, Krishnaswamy and Mustapha (2021), food safety is critical, especially when preparing foods for young children because of their premature immune systems. Therefore, this study utilised a Hazard Analysis Critical Control Point (HACCP) plan to identify potential hazards associated with producing a sorghum and pearl millet-based instant porridge, assess the risk level, and establish control measures. The purpose was to aid in producing a high-quality instant porridge that is safe to ingest by school learners. The chance of a hazard occurrence was assessed, and methods for limiting or preventing hazard occurrence were implemented. Table 3.2 outlines the HACCP strategy used during the production of a sorghum and pearl millet-based instant porridge.

Table 3. 2: HACCP plan for the production of a sorghum and pearl millet-based instant porridge

Process Step	**Hazard**	**Control Measure**	**Critical Limit**	**Monitoring Procedures**	**Corrective Action**	**Severity**	**Likeli-hood**	**Risk**
Sourcing of ingredient	Biological	Source ingredients from reputable suppliers; inspect quality of ingredients.	N/A	Inspect deliveries for contamination and quality	Reject contaminated ingredients	High	Medium	High
Fermentation Process	Microbial (pathogens)	Control fermentation time and temperature	Temperature: 37°C; Time: 24 hours	Regular monitoring of temperature and pH	Adjust fermentation time or temperature; discard under fermented or over fermented batch	High	Medium	High
Cooking	Biological (cross-contamination) ; nutrient loss from overcooking	Use sanitised equipment; control cooking time and temperature	Temperature should not exceed 100°C for an extended period of time	Monitor cooking temperature (use food thermometer) and time	Sanitise equipment; adjust cooking time; reheat to required temperature if necessary	High	Medium	High
Drying	Chemical (residue from cleaning agents)	Use food-grade cleaning agents; rinse thoroughly	Temperature: 60°C for specified drying time	Monitor drying time and temperature	Extend drying time; check moisture content	Medium	Low	Medi um
Packaging	Biological (contaminated packaging)	Use food-grade, hygienically stored packaging; inspect prior to use	N/A	Inspect every batch of packaging	Discard contaminated or damaged packages	Medium	Low	Medi um
Storage	Biological & chemical (spoilage, infestation)	Maintain appropriate storage conditions (temp/humidity)	Temp: below 25°C; Humidity: below 60%	Regularly check storage conditions	Adjust storage conditions; inspect for spoilage or pest	High	Medium	High
Final Product	Microbial (pathogens in final product	Perform microbiological testing	N/A	Test finished product upon batch completion	Reprocess or discard contaminated batch	High	Low	Medi um

3.6.2.6 Sensory assessment

A 9-point hedonic scale (refer to Appendix I) was used to assess the sensory perception of the developed instant porridge among eight DUT students who were frequent consumers of instant breakfast cereals. The 9-point hedonic scale was designed to assess the degree of likeness of a new product using nine verbal categories that range from 'dislike extremely' to 'like extremely' (Heymann and Lawless 2013). The sensory assessment was conducted in a controlled environment (Figure 3.3) with the help of a trained fieldworker. Participants were seated 1.5 metres apart. The study was explained to the sensory assessment participants prior to taking part in the sensory assessment. Each participant received a letter of information outlining the goals, objectives, procedures, and advantages, which were presented both orally and in writing (refer to Appendix J). The participants willingly agreed to participate in the study by signing a consent form (refer to Appendix K). Each willing participant was informed that they could withdraw their participation in the research at any time.

The instant breakfast formulation was improved based on feedback from the sensory assessment until the instant porridge was deemed as being sensory acceptable. Upon the successful development of a sensory-acceptable breakfast cereal, the breakfast cereal was subjected to nutrient, microbial, and shelf-life analysis.

3.6.2.7 Microbial testing

The microbiological testing was conducted by a laboratory approved by the South African National Accreditation System (SANAS) using the International Standards Organisation (ISO) and South African Bureau of Standards (SABS) methodology for microbial testing of foods (Regulations governing microbial standards for foodstuffs and related matters 1997). A yeast and mould test, a total aerobic plate count, and a coliform bacteria count were performed on the sorghum and millet instant porridge. These tests seek to ascertain whether the developed product is safe for consumption and commercialisation, as well as whether any hazardous microbes are present (Heredia, Wesley and Garcia 2009).

The following procedures were applied based on food microbiological analysis:

• 90 ml of sterile, distilled water was used to aseptically dilute a 10g porridge sample.

• Using the pour plate method, serial dilutions were plated out onto agar plates.

• Yeast and mould counts were performed using potato dextrose agar, coliform bacteria were counted using violet red bile agar, and total aerobic bacteria were counted using plate count agar.

3.6.2.8 Nutritional analysis

In accordance with SANAS guidelines, the final form of the sorghum and millet instant porridge underwent nutritional testing at a laboratory that was approved by the Association of Analytical Chemists International (George 2024). The Kjeldahl Method was used to determine the protein content of the instant cereal by diluting the product in a strong acid to release nitrogen, which was subsequently evaluated by a suitable titration procedure. The nitrogen content of the food was used to calculate how much protein was still present. The Soxhlet method, which extracts the fat from the sample using a solvent, was used to determine how much fat was in the instant cereal. The retrieved fat was then weighed. The carbohydrate content was determined using the difference, which means that the measured amounts of protein, fat, ash, and moisture were subtracted from the total weight to determine the approximate carbohydrate value. A food calorimeter was used to determine the number of calories per gram of the instant porridge. The fibre content was also determined, as most South African diets lack fibre, and sorghum and millet are rich sources of fibre. The instant cereal was also subjected to micronutrient testing for magnesium, zinc, iron, magnesium, manganese, potassium, phosphorus and B vitamins.

3.6.2.9 Shelf-life testing

The length of time that the sorghum and millet instant cereal could be stored in its final packaging before experiencing quality, structural, and microbiological degradation was ascertained using accelerated shelf-life testing (Graf and Saguy 1991). The product was stored under accelerated storage conditions (55°C) and subjected to quality and microbiological standards testing until it was deemed unsuitable for shelf life testing (Hidayati, Sartika and Fudholi 2022).

3.6.3 Phase 3

3.6.3.1 Learner sensory assessment

The Principals of the schools provided the researcher with a copy of all the class registers for learners in the selected grades. Stratified random sampling was used to select 200 learners from the four schools, ensuring diversity across grades and school types, and proportional allocation based on the total sample size. Each learner received a letter of information outlining the goals,

objectives, procedures, and advantages [of the assessment], which were presented both orally and in writing (refer to Appendix L). Furthermore, letters of information (refer to Appendix M) and consent forms (refer to Appendix F) were sent to parents via the designated teacher. Learners who obtained their parent's consent then indicated assent (refer to Appendix N) if they wanted to participate in the sensory assessment.

Once the completed consent and assent forms were collected, the researcher created a register to ensure that only the learners who received parental consent and gave assent participated in the learner sensory assessment. The learner sensory assessment sample comprised 50 learners per school from the four schools (n=200).

The researcher created the samples for the learner sensory assessment with the help of a research assistant from DUT's Department of Consumer Science: Food and Nutrition. The research assistant was deemed eligible to assist due to their basic food hygiene expertise (Institute of Food Science and Technology 2015). The instant breakfast cereal was then transported to the schools in dry, sealed containers to avoid contact with moisture and contaminants. The cereal was reconstituted by the addition of warm water in a clean classroom to conduct the sensory assessment at the schools. The researcher and research assistant wore disposable gloves while reconstituting the breakfast cereal and also made sure that all the equipment that was used during the reconstitution were washed and disinfected before use to minimise the risk of cross-contamination. Additionally, constant hand washing and hand sanitising were practised to further guarantee that a clean and safe environment was maintained for the learners who took part in the sensory assessment.

A seven-point facial hedonic rating scale with verbal anchors was used in the learner sensory assessment questionnaire (refer to Appendix O). The faces represented the participant's level of liking or disliking the product, which is considered age-appropriate for children as young as 4 years (Kimmel *et al*. 1994). According to (Meilgaard, Carr and Civille 2006), using pictures in rating scales is easier for primary school learners to understand and grasp. The learner sensory assessment questionnaire was validated in a pilot study that included ten participants representative of the sample population. Each participant received a copy of the questionnaire, and they were asked if the accompanying visuals and verbal anchors were clear. According to the pilot study's findings, the learners were confused by the terms 'male' and 'female', which were changed to

'boy' and 'girl' to eliminate confusion and ensure that the questionnaire was suitable for the target age range.

To avoid interfering with the academic curriculum, the researcher worked with the principals in each school to set up a time and date that worked for everyone. On the day of the assessment, learners on the register who had returned a completed consent form were taken to the venue where the sensory assessment was set up. Prior to the sensory assessment, the tables were prepared with, a cracker (a palate cleanser), serviette, water, teaspoon, a 5g sample of the breakfast cereal, pen and a sensory evaluation form as seen in Figure 3.5.

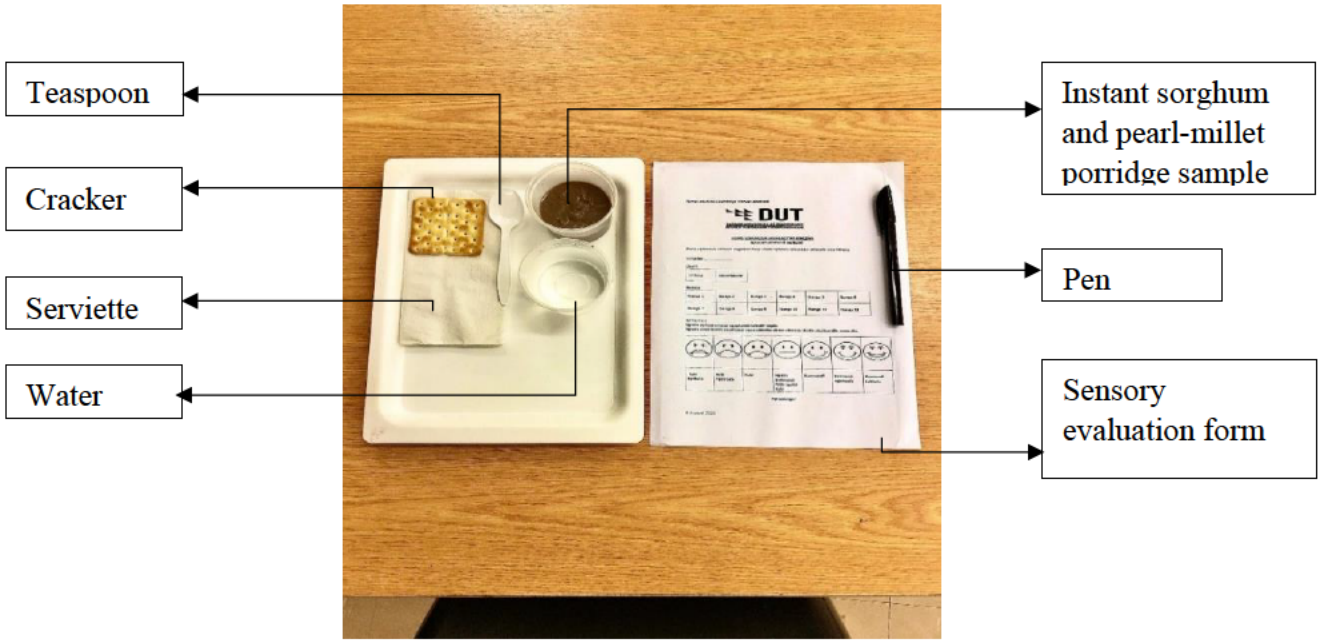


Figure 3.5: Image showing the set-up for learner sensory assessment

Figure 3.5 shows the set-up for the sensory assessment of the breakfast porridge at the schools. Learners were told there were no wrong answers and were asked to respond as honestly as possible. Ten minutes were allocated for each learner to participate in the sensory assessment of the instant porridge. After the sensory assessment, the questionnaires were collected and counted. Findings from the learner acceptance sensory assessment questionnaire data were recorded on an Excel spreadsheet.

3.7 Statistical analysis

A Microsoft Excel® spreadsheet was used to capture the data, which was then processed and is shown in Chapter 4 as tables and graphs. The findings of the breakfast requirements assessment and preference questionnaire and the sensory acceptance assessment questionnaire were statistically analysed using the Statistical Package of Social Sciences (SPSS) (software version 291BM Corp, Armonk, NY, USA). The chi-square test of independence was used to look for variations across age and gender, and the chi-square goodness-of-fit test was performed to see if there was a significant difference in preference for the breakfast porridge cereal. Means were compared using an independent sample t-test, and linear connections between variables were examined using Pearson's correlation test.

3.8 Validity

The degree to which the study's notion can be precisely quantified is known as validity (Heale and Twycross 2015). Validity, often known as accuracy, is the degree to which a measurement or research result approximates reality (Myer *et al.* 2007). Consequently, the extent to which a measuring tool measures what it is supposed to measure is referred to as its validity (Delport and Roestenburg 2011).

Content validity, also known as face validity, is the fundamental form of instrument validation, assessing the extent to which an indicator accurately represents the fundamental content of a phenomenon (DePoy 2019). The research supervisors and the statistician reviewed the questionnaire to ensure content validity. According to Sürücü and Maslakçı (2020), construct validity is the assessment of how well interventions and measured variables reflect specific components. Sensory assessments were conducted during the product development trials using a validated 9-point Hedonic scale to ensure construct validity. Additionally, the learner sensory assessment was conducted using a validated 7-point facial hedonic rating scale (Hassanally 2020). This was carried out to ensure that the verbal and visual anchors utilised were appropriate for the target age range.

3.9 Reliability

The capacity of an instrument to produce consistent data each time it is used is known as reliability (Delport and Roestenburg 2011). Reliability is mainly concerned with how well something is assessed, not with what is being measured (Delport and Roestenburg 2011). By pilot testing the

questionnaire and eliminating questions that were ‘confusing’, reliability was preserved. School learners participated in a pilot study of the breakfast needs assessment questionnaire to ensure reliability. The learners who participated in the pilot study were excluded from the actual study. Adjustments were made based on feedback from the pilot study to increase the focus and relevance of the questionnaire. This was done to simplify the questionnaire and ensure the language was appropriate for the target age range by eliminating ambiguous terminology.

3.10 Reduction of bias and data quality management

During data collection, the researcher ensured that learners completed the breakfast needs assessment and preference questionnaire and the learner acceptance sensory assessment questionnaire. To conduct the learner sensory assessment, the learners were seated about one metre apart. This made it impossible for the responses to be copied. The learners were also told not to speak to one another during the assessment.

Furthermore, the same preparation conditions, utensils and equipment were used to prepare the breakfast cereal to conduct a sensory assessment at each of the various schools. Additionally, all samples were created using the same brand of ingredients.

The researcher captured data from the breakfast needs assessment, preference questionnaire and the learner sensory assessment questionnaire on a Microsoft Excel spreadsheet. The statistician and the chief supervisor double-checked the data input for correctness. Data quality was maintained throughout the collecting, coding, and cleaning procedures through careful recording, appropriate coding, and adequate cleaning to eliminate inconsistencies. Electronic data was password-protected, and all hard copies were kept in sealed boxes in a safe location in the DUT Department of Food and Nutrition. The data was only accessible to the statistician, supervisors, and researcher.

3.11 Ethical considerations

Permission from the relevant gatekeepers was obtained prior to starting the methodological processes to ensure that the techniques and procedures used in the study were ethically acceptable:

- The research proposal was reviewed and approved by the KZN Department of Education's (DoE) (refer to Appendix B and Appendix C) research office ethics committees, as well as DUT’s Institutional Research Ethics Committee (IREC) (refer to Appendix P). The student

received ethical approval from the KZN DoE research office to perform studies at the chosen schools, and from DUT IREC to conduct sensory evaluations among DUT students.

- Following clearance from the KZN DoE, the researcher visited the four school principals to discuss the study's goal and get permission to do more research.
- Parents received letters of information and consent letters from the respective educators. Learners who obtained their parents' approval gave their consent if they decided to participate in the study. DUT students were also given information letters and consent forms permitting them to participate in the study. Consent and assent were obtained in this manner at various stages of the investigation. Participants were informed that they were free to withdraw from the research at any time and that participation was voluntary.
- Participants with common food allergies were omitted from the research to ensure their well-being.
- The researcher and research assistant wore full chef's uniforms to prevent cross-contamination while preparing samples.
- The research team collected data anonymously for scholarly purposes. No personally identifying data, such as names or email addresses, were gathered. To safeguard participants' information, the researcher and supervisor were the only people accessing the data. Participants did not bear any of the costs connected with their participation in the study.

3.12 Conclusion

Chapter 3 provides a comprehensive description and explanation of the procedures researchers used to obtain data. The researcher made every attempt to guarantee that the research was carried out in an honest, scholarly, and scientifically sound manner. A systematic methodology was employed, aiding in the consistent collection of data. The study's findings will be presented and discussed in the following chapter.

CHAPTER 4: RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents the results and findings obtained from the quantitative data in this study. The results obtained from the learner's breakfast needs assessment and preference survey, product development, learner sensory assessment, microbiological tests, nutritional tests, and shelf-life tests will be presented. Results are presented as descriptive statistics in the form of graphs, cross-tabulations and figures. Inferential techniques, including correlations and chi-square test values, are interpreted using p-values.

4.2 Breakfast needs assessment and preference survey

The breakfast needs assessment, and preference survey addressed the study's first objective, which aimed to investigate the need for breakfast, identify barriers preventing school learners from eating breakfast, and understand learners' breakfast preferences. The insights gained from this objective were used to inform the development of a sorghum and millet-based instant breakfast cereal suitable for the NSNP. Four hundred and five learners participated in the breakfast needs assessment and preference survey.

4.2.1 Demographics

The demographic profile of the learners from each of the five geographic areas covered gender, age, and grade.

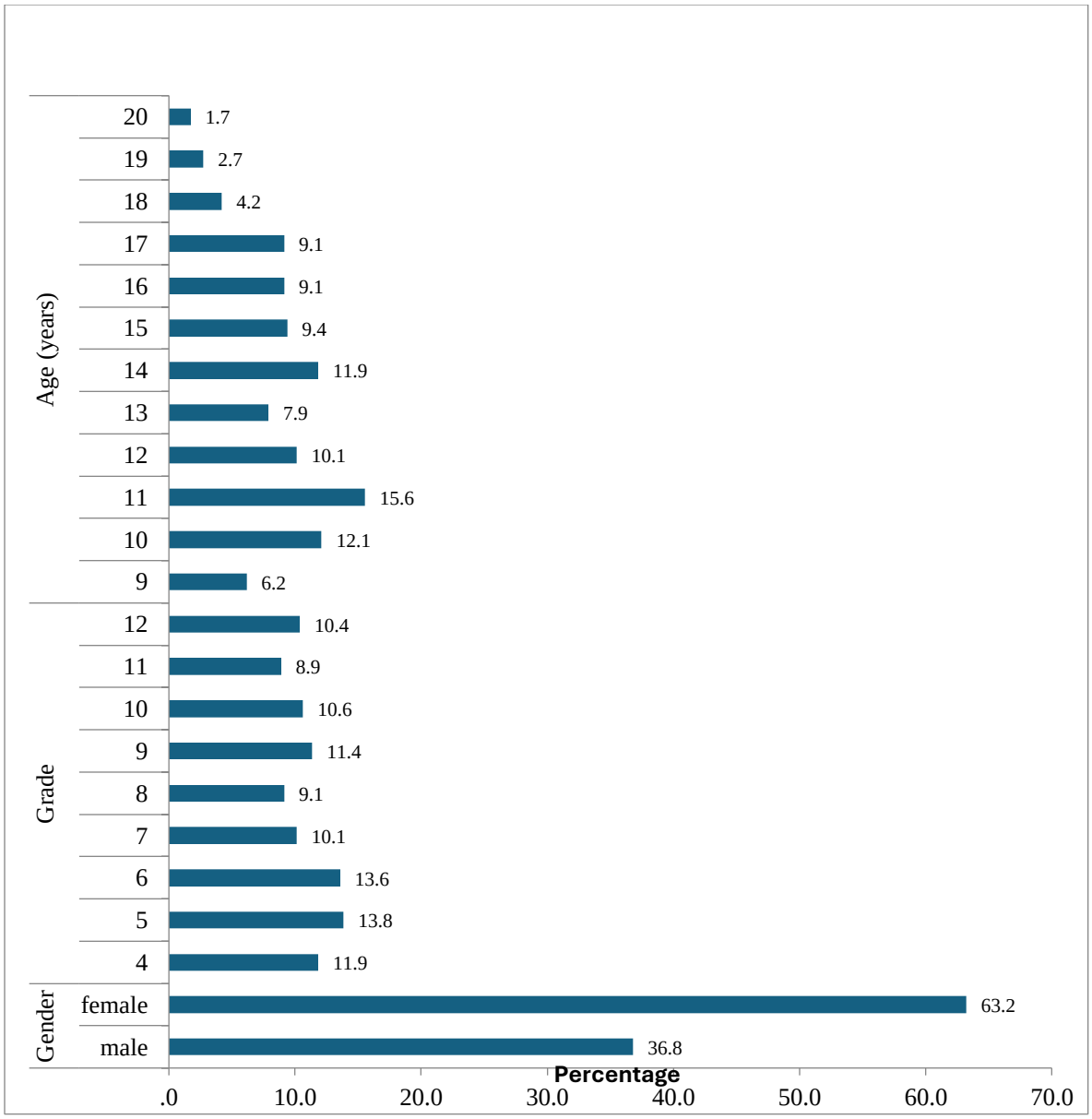


Figure 4. 1: Learners demographic profile (n=405)

Figure 4.1 depicts the demographic profile of school learners (n=405), of which 63.2% (n=256) were girls compared to boys at 36.8% (n=149). In terms of grade, 11.9% (n=48) of the participants were from grade 4, 13.8% (n=56) from grade 5, 13.6% from grade 6 (n=55), and 12.1% (n=41) from grade 7. Furthermore, 9.1% (n=37) of the learners were from grade 8, 11.6% (n=47) from grade 9, 10.6% (n=43) from grade 10, 8.9% (n=36) from grade 11 and 10.4% (n=42) were from grade 12. Regarding the age range of learners, 6.2% (n=25) of the learners were below the age of 10 years, 67% (n=271) were between 10-15 years, and 26.8% (n=109) were between 16-20 years.

4.2.2 Breakfast consumption patterns

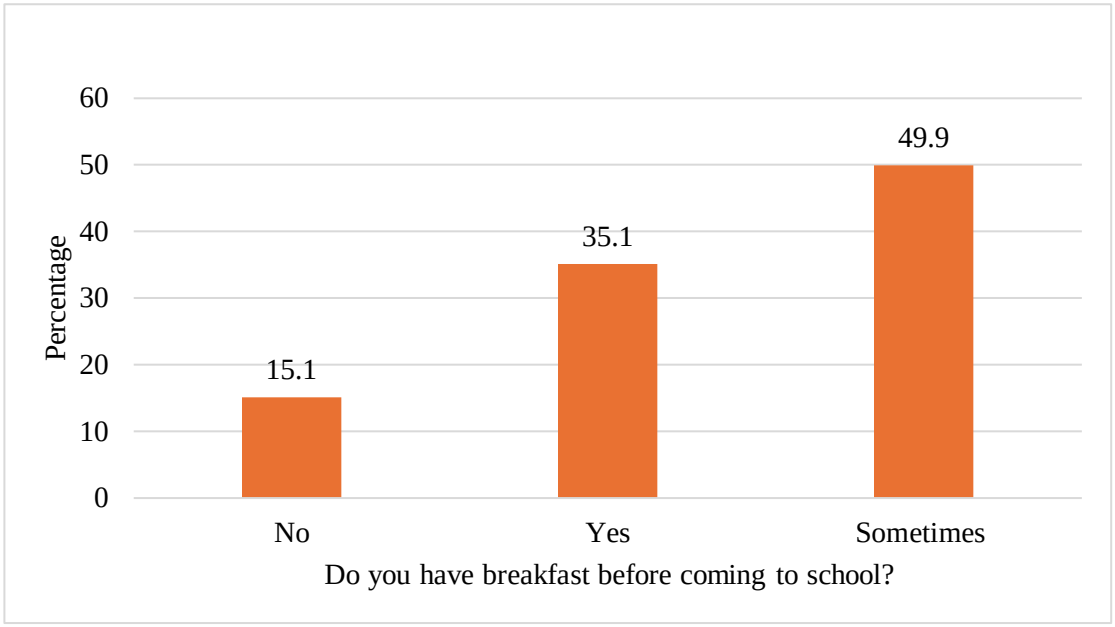


Figure 4. 2: Breakfast consumption before school by learners (n=405)

Learners were asked whether they generally eat breakfast before arriving at school and their responses are presented in Figure 4.2. Having no breakfast before coming to school was selected by 15.1% (n=61) of the learners, with 35.1% (n=142) reporting "yes" to consuming breakfast, and 49.9% (n=202) reporting to sometimes consume breakfast.

Table 4. 1: Chi-square goodness-of-fit-test on the consumption of breakfast before school (n=405)

	Responses as Frequency (%)			X^2	df	p-value
	no	yes	sometimes			
Do you have breakfast before coming to school?	61 (15.1)	**142 (35.1)**	**202 (49.9)**	74.178	2	<.001

*indicates significance at the 95% level

Table 4.1 represents the chi-square goodness-of-fit test on the frequency of consumption of breakfast before school on a general basis. A significant percentage of school learners consumed breakfast (35.1%) or sometimes consumed breakfast (49.9%) $p<0.001$.

Table 4. 2: Chi-square goodness-of-fit-test on reasons for not consuming breakfast before school (n=259)

	Responses as Frequency (%)				X^2	df	p-value
	Too early to eat.	No time to eat.	Not enough food to eat.	Other			
If you answered "No" or "Sometimes" for the above question, why do you not have breakfast?	25 (9.5)	**149 (56.7)**	79 (30.0)	6 (2.3)	74.178	2	<.001*

*indicates significance at the 95% level

Table 4.2 presents the Chi-square goodness-of-fit-test on the reasons for not consuming breakfast before school. Although 61 learners skipped breakfast and 202 learners sometimes consumed breakfast, only 259 learners provided reasons why they always or sometimes skipped breakfast. A significant percentage of the school learners who answered "no" or "sometimes" indicated that they did not consume breakfast because they did not have time to eat (56.7%) $p<.001$. Other learners did not consume breakfast because there was not enough food (30.0%), it was too early to eat (9.5%), and for other reasons (2.3%). Among the 2.3% of learners who selected "other", the following reasons were cited for not having breakfast, feeling full, waking up to load shedding, unavailability of food, attempting weight loss, and experiencing stomach cramps.

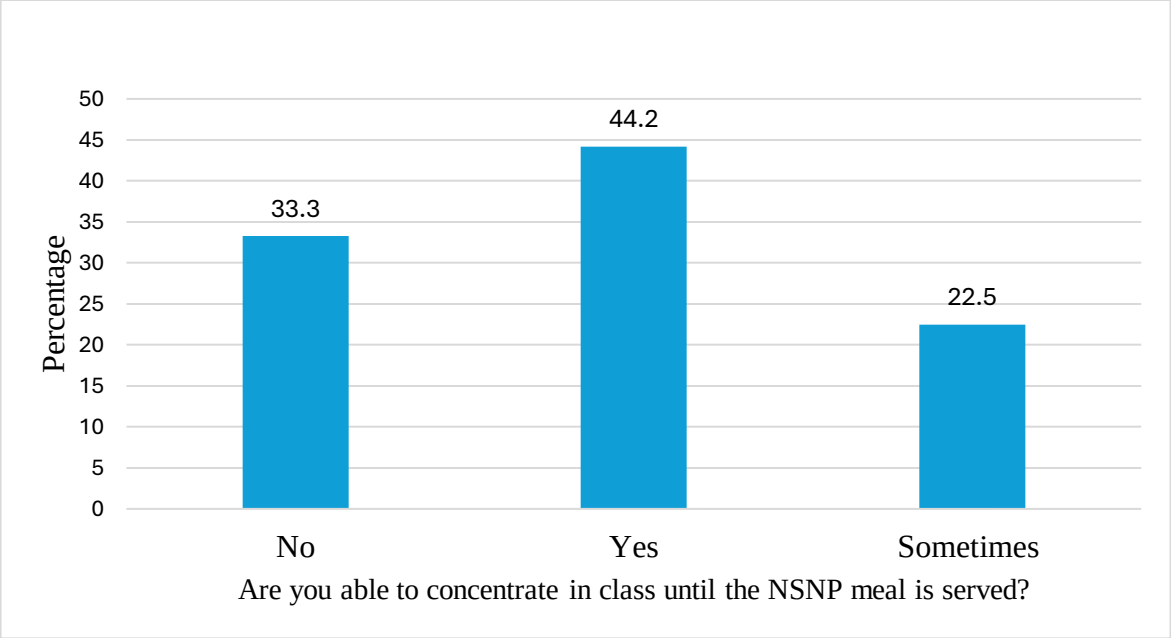


Figure 4. 3: Learner's ability to concentrate in class without eating breakfast (n=405)

Results of the assessment of the learner's ability to concentrate in class without eating breakfast are presented in Figure 4.3. The results show that 33.3% (n=135) of the learners were unable to concentrate, 44.2% (n=179) were able to concentrate, and 22.5% (n=91) were able to concentrate sometimes, until the NSNP meal was served.

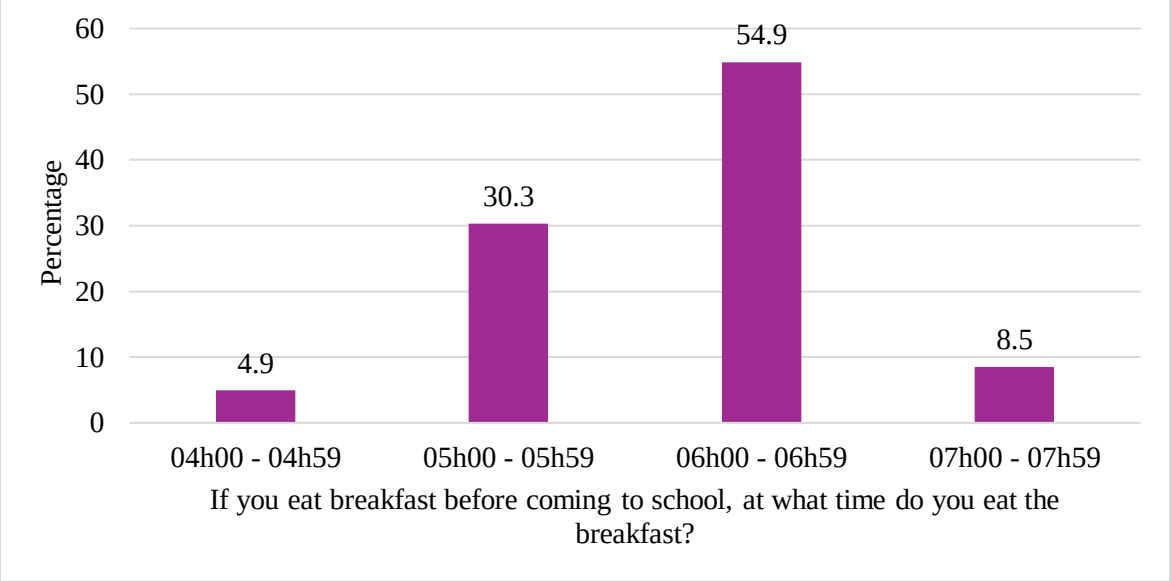


Figure 4. 4: Preferred timing of breakfast consumption before school (n=405)

The majority of learners (54.9%, n = 78) reported having breakfast between 06:00 and 06:59 in the morning (Figure 4.4), followed by 30.3% (n = 43) who ate breakfast between 05:00 and 05:59.

A smaller proportion, 4.9% (n = 7), consumed breakfast between 04:00 and 04:59, while 8.5% (n = 12) ate breakfast between 07:00 and 07:59.

Table 4. 3: Chi-square goodness-of-fit-test on the breakfast consumption timing among learners before school (n=140)

	Responses as Frequency (%)				X^2	df	p-value
	04h00-04h59	05h00-05h59	06h00-06h59	07h00-07h59			
If you eat breakfast before school, at what time do you eat breakfast?	7 (4.9)	**43 (30.3)**	**78 (54.9)**	12 (8.5)	92.171	3	<.001*

*indicates significance at the 95% level

Table 4.3 presents the Chi-square goodness-of-fit test on the breakfast consumption timing among learners before school. A significant percentage of the school learners indicated that they consumed breakfast between 05:00 and 05:59 (30.3%), and between 06:00 and 06:59 (54.9%) p<0.001.

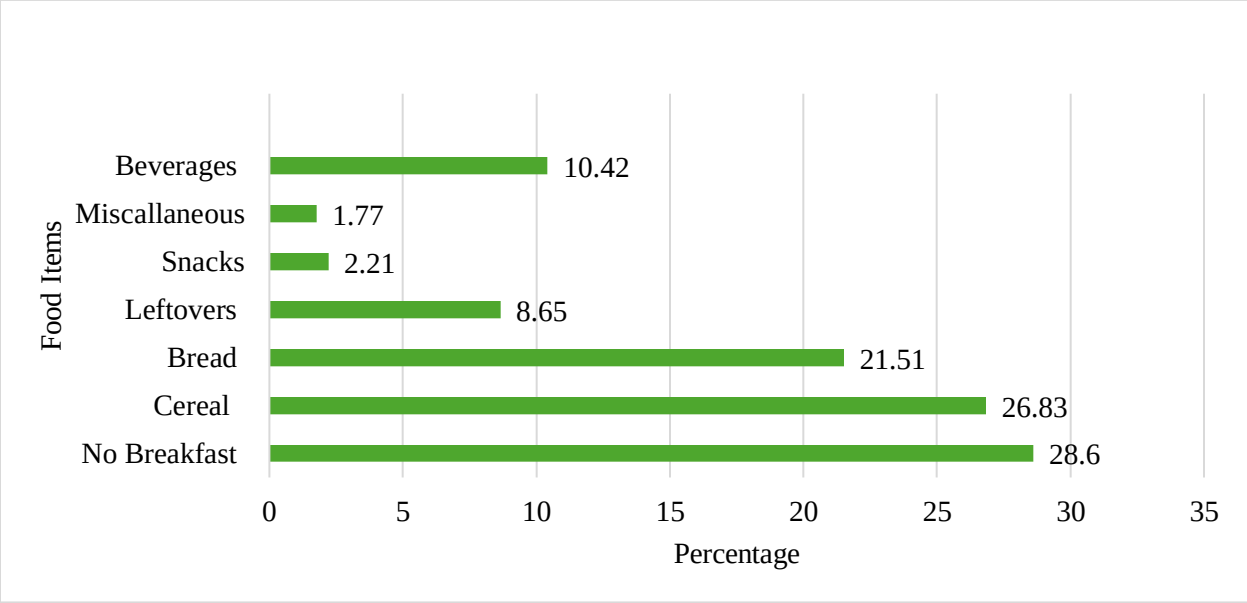


Figure 4. 5: Breakfast items consumed among school learners (n=405)

The foods consumed by learners for breakfast on the day that the questionnaire was administered are shown in Figure 4.5. A considerable percentage of learners (28.6%) reported that they did not consume breakfast. Cereal was the most popular breakfast item, consumed by 26.83% of the learners. Bread was consumed by 21.51% of the learners, making it the second most popular breakfast option. For breakfast, 8.65% of learners consumed leftovers. A very small percentage of learners (2.12%) consumed snacks for breakfast. The percentage of learners who consumed various foods was 1.77%. Of the learners who consumed breakfast, 10.42% reported they paired breakfast with beverages.

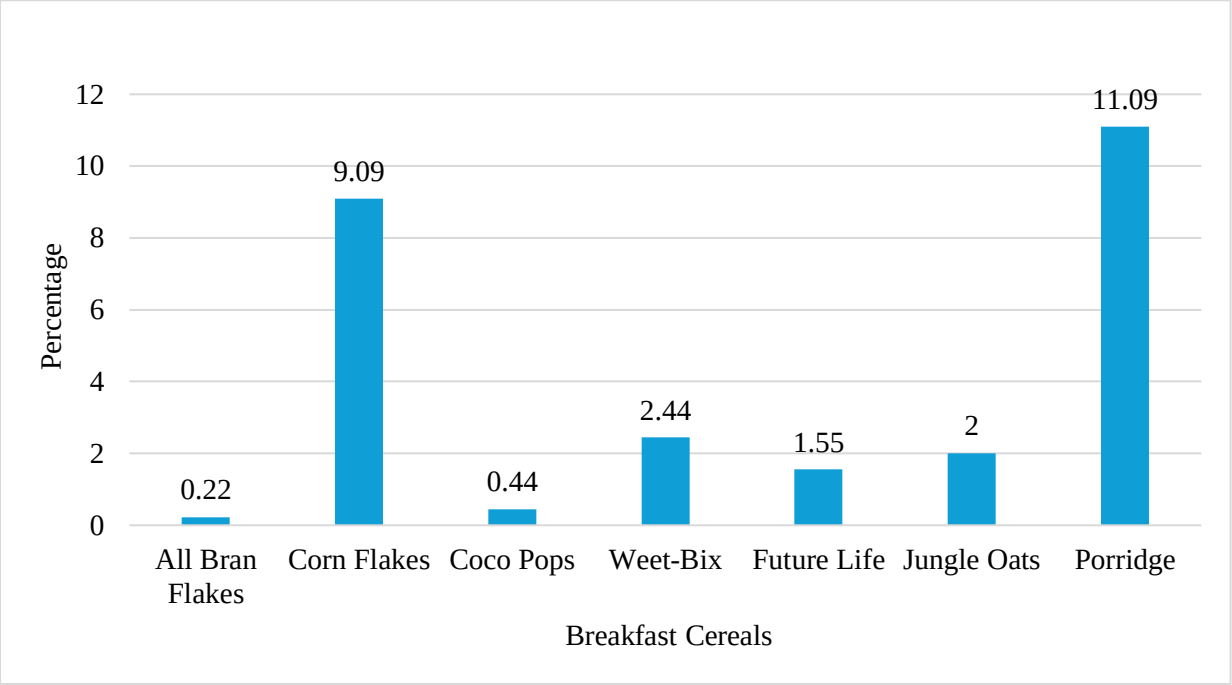


Figure 4. 6: Breakfast cereals consumed by school learners (n=121)

As illustrated in Figure 4.5, cereals were the most popular breakfast food option consumed by school learners, accounting for 26.83%. Figure 4.6 illustrates the various breakfast cereals consumed by school learners. Porridge emerged as the most popular choice, selected by 11.09% of learners (n=50). Corn Flakes ranked as the second most preferred cereal, consumed by 9.99% (n = 41) of learners. Other cereals, including All Bran Flakes, Coco Pops, Weet-Bix, Future Life, and Jungle Oats, were consumed by smaller percentages of learners.

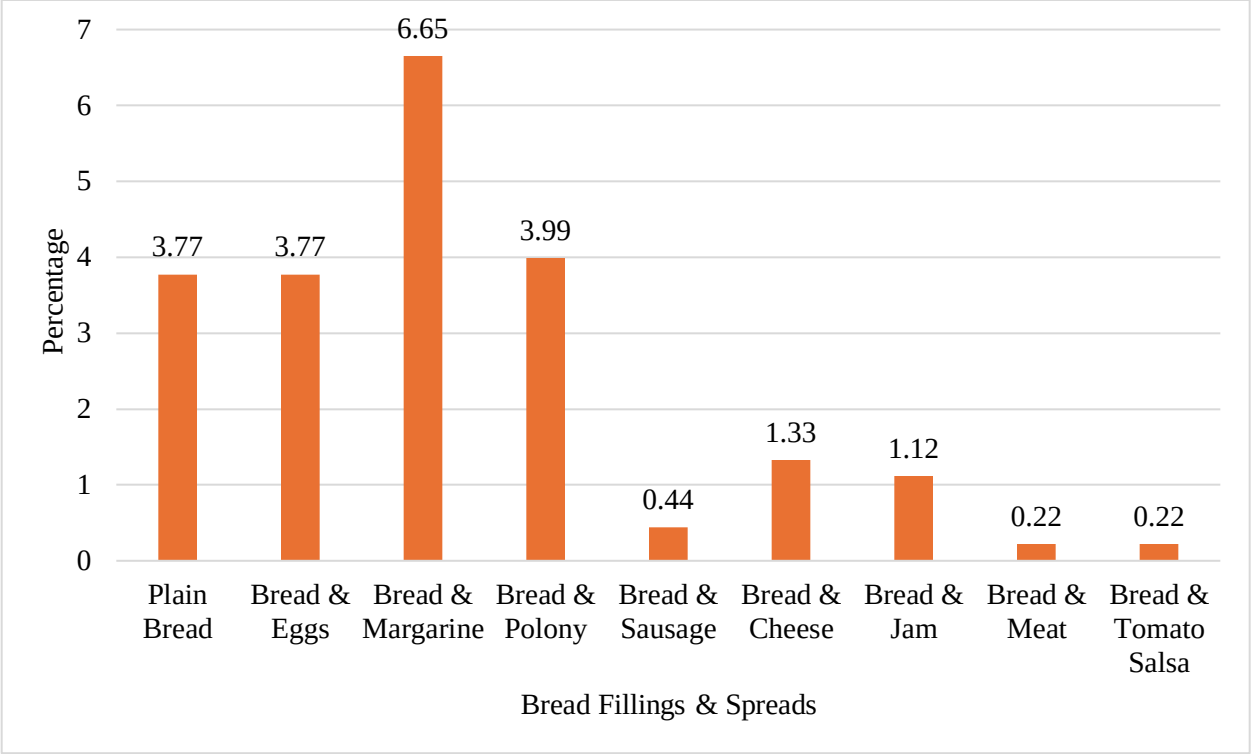
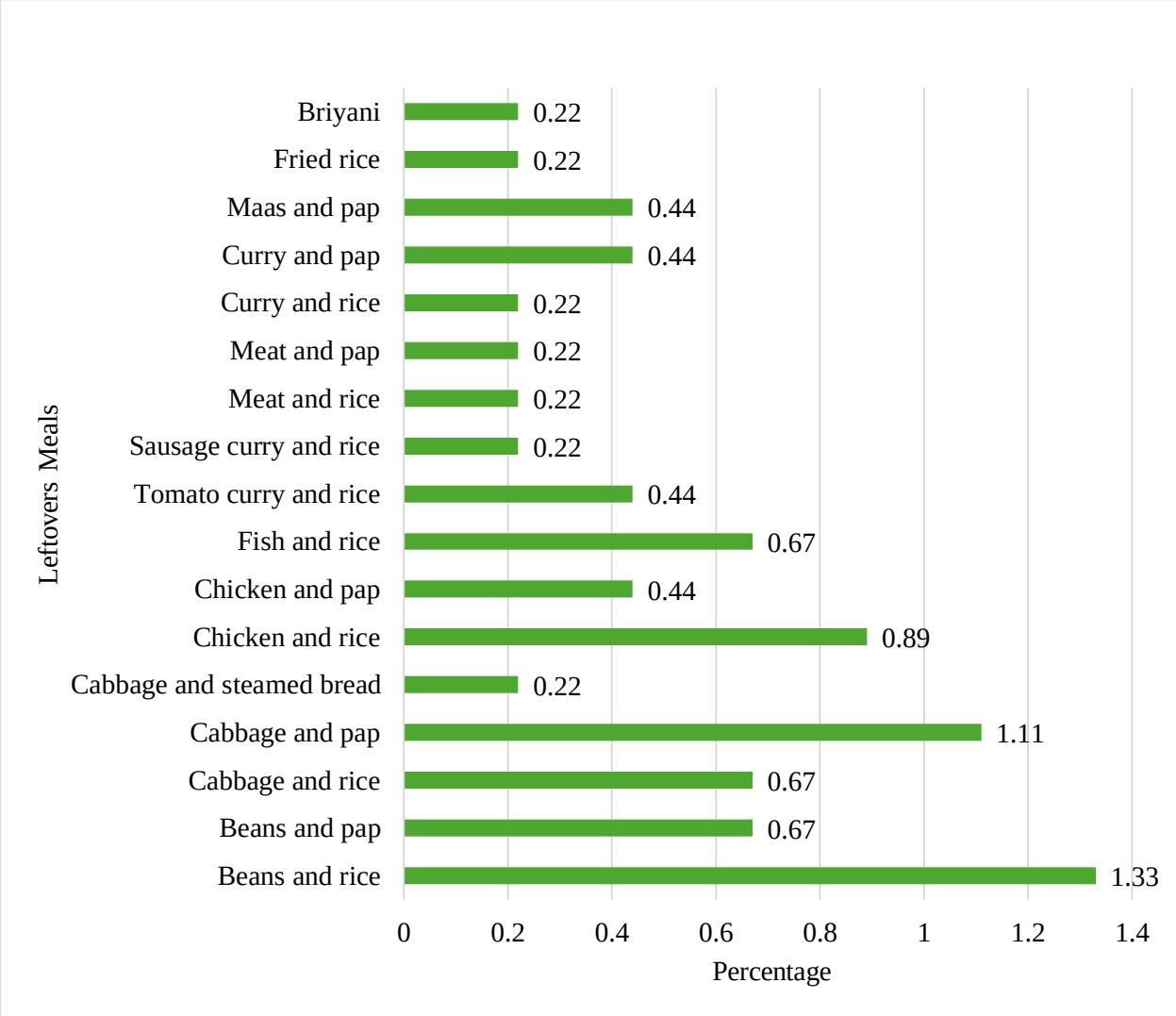


Figure 4. 7: Other breakfast items consumed among school learners (n=97)

Figure 4.7 illustrates that bread was also a popular breakfast choice among school learners (n=97). A variety of fillings and spreads accompanied this choice. Margarine was the most popular spread, consumed by 30 learners (6.65%), followed by polony, which was consumed by 18 learners (3.99%). Plain bread was consumed by the same number of learners who consumed bread with eggs (3.77%, n=17). Bread served with a sausage was consumed by a small proportion of learners (0.44%, n=2). Similarly, the consumption of cheese and jam was minimal, with 1.33% (n=6) and 1.12% (n=5) of learners opting for it as a filling, respectively. Additionally, meat (0.22%) and tomato salsa (0.22%) were the least consumed bread fillings, each being selected by one learner.

Figure 4. 8: Consumption of leftovers among school learners (n=39)

Leftovers from previous meals were also incorporated into breakfast meals by 8.65% of the learners. Beans and rice were a popular choice, with 1.33% (n=6), followed by cabbage and pap (1.11%, n=5). Beans and pap, cabbage and rice, and fish and rice were consumed by the same number of learners (n=3). Other options, such as maas and pap, curry and pap, tomato curry and rice, and chicken and pap, were chosen by two learners (0.44%), respectively. Various leftovers, such as curry and rice, meat and pap, meat and rice, sausage curry and rice and cabbage and steamed bread, were consumed by one learner each (0.22%).



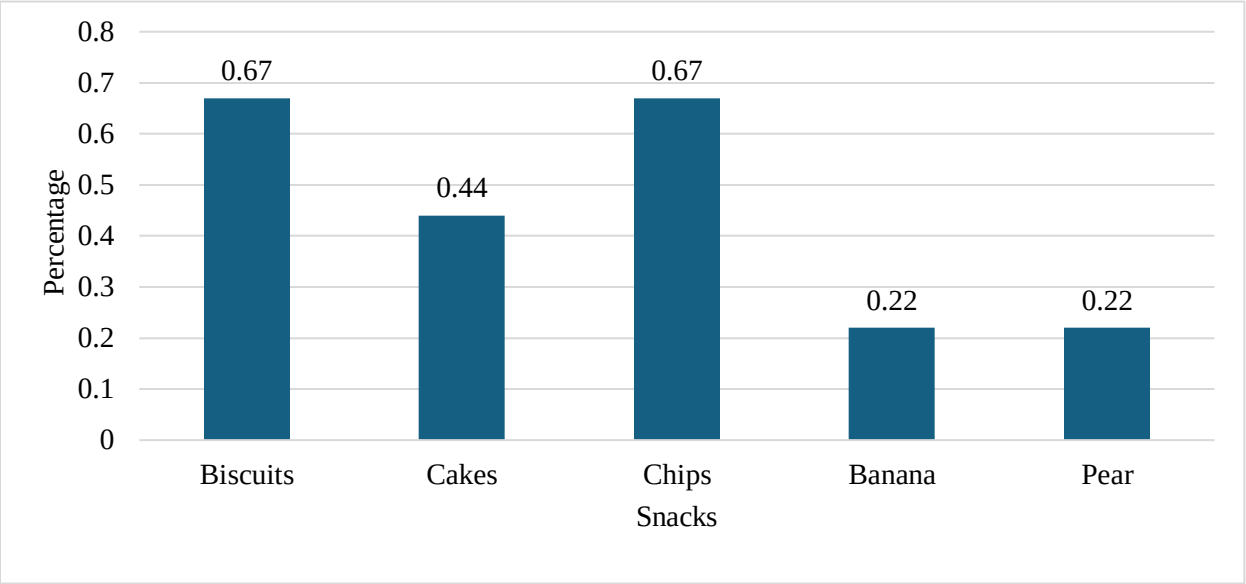


Figure 4. 9: Consumption of snacks for breakfast by learners (n=10).

According to the study findings (Figure 4.9), a small proportion of learners (2.2%) consumed snacks such as baked goods, chips and fruits for breakfast. The consumption of baked goods was minimal, with only three learners (0.67%) eating biscuits and three learners (0.67%) eating cakes out of the total sample size. Similarly, the chips category was less prominent, with three (0.67%) learners consuming chips. Additionally, only one learner (0.22%) ate a banana, and another learner (0.22%) ate a pear, indicating a low level of fruit intake.

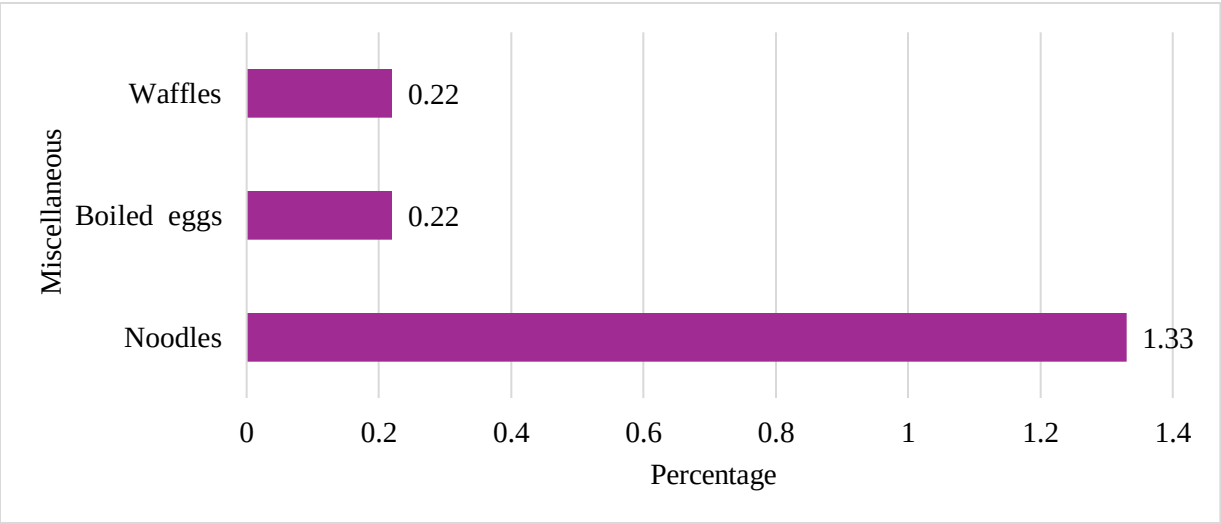


Figure 4. 10: Miscellaneous items consumed by learners for breakfast (n=8)

Figure 4.10 depicts that 1.77% (n=8) of the learners consumed miscellaneous items for breakfast. The learners ate a variety of foods, including noodles, boiled eggs and waffles. Noodles were a unique breakfast choice, with six learners (1.48%) opting for them. In addition, a banana was consumed by just one learner (0.22%), and a pear by one learner (0.22%).

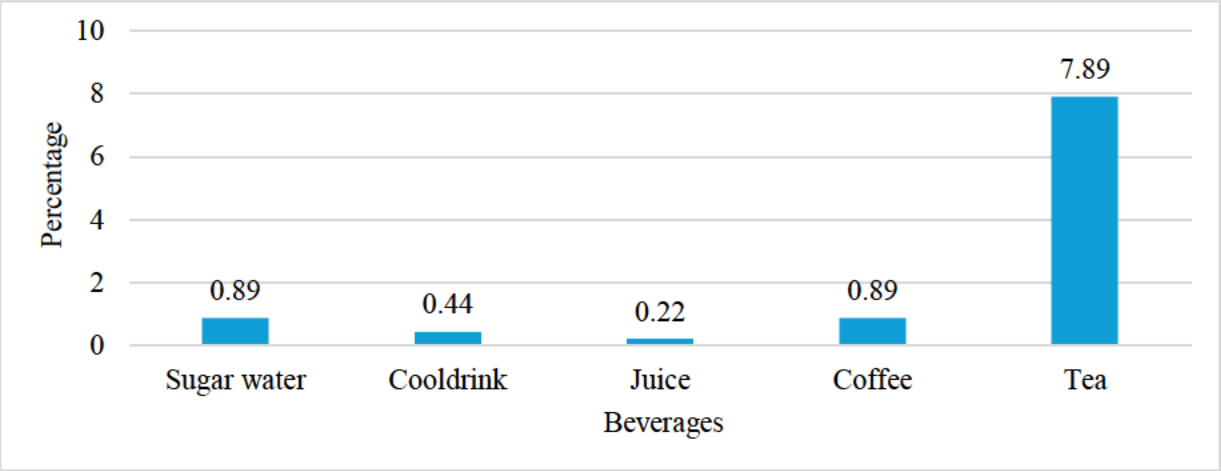


Figure 4. 11: Beverages consumed for breakfast by school learners (n=47)

Figure 4.11 displays the various consumed beverages. Tea was the most popular choice among learners, with 7.89% (n=36) opting for it. Sugar water (n=4), cooldrink (n=2), juice (n=1) and coffee (n=4) followed as less popular choices

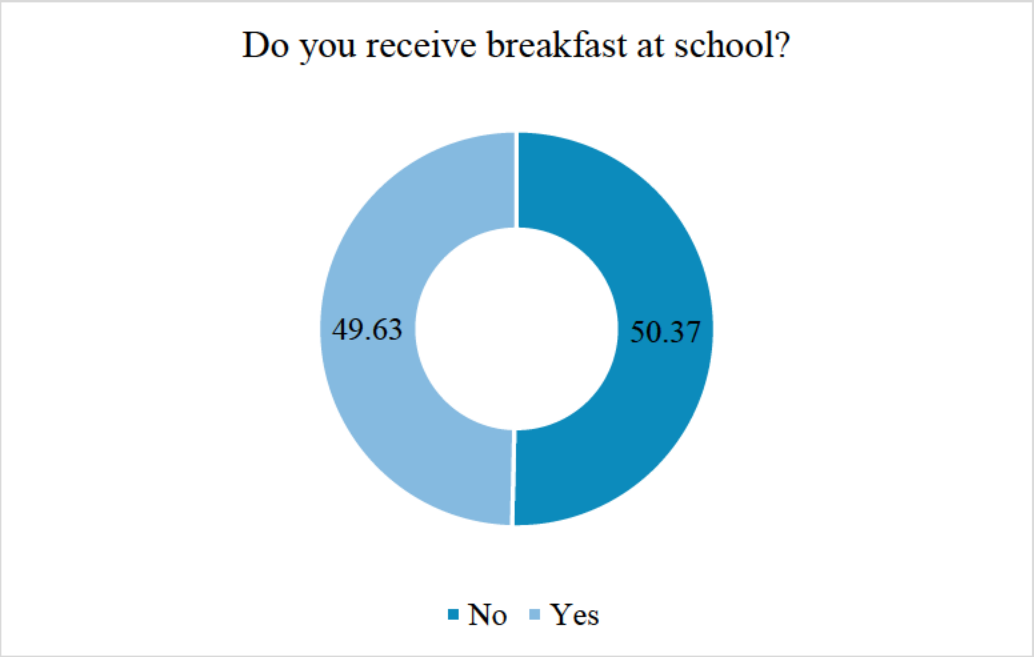


Figure 4. 12: School breakfast provisioning (n=405)

The results regarding the presence of a breakfast programme at schools (Figure 4.12) reveal a nearly even split among learners, with high school learners (50.37%; n=204) indicating that their school does not provide a breakfast programme, while primary school learners (49.63%; n=201) affirmed that their school offers breakfast. Of the 201 learners who receive breakfast at school, a substantial majority described the food offered as porridge (n=199).

4.2.3 Breakfast preferences

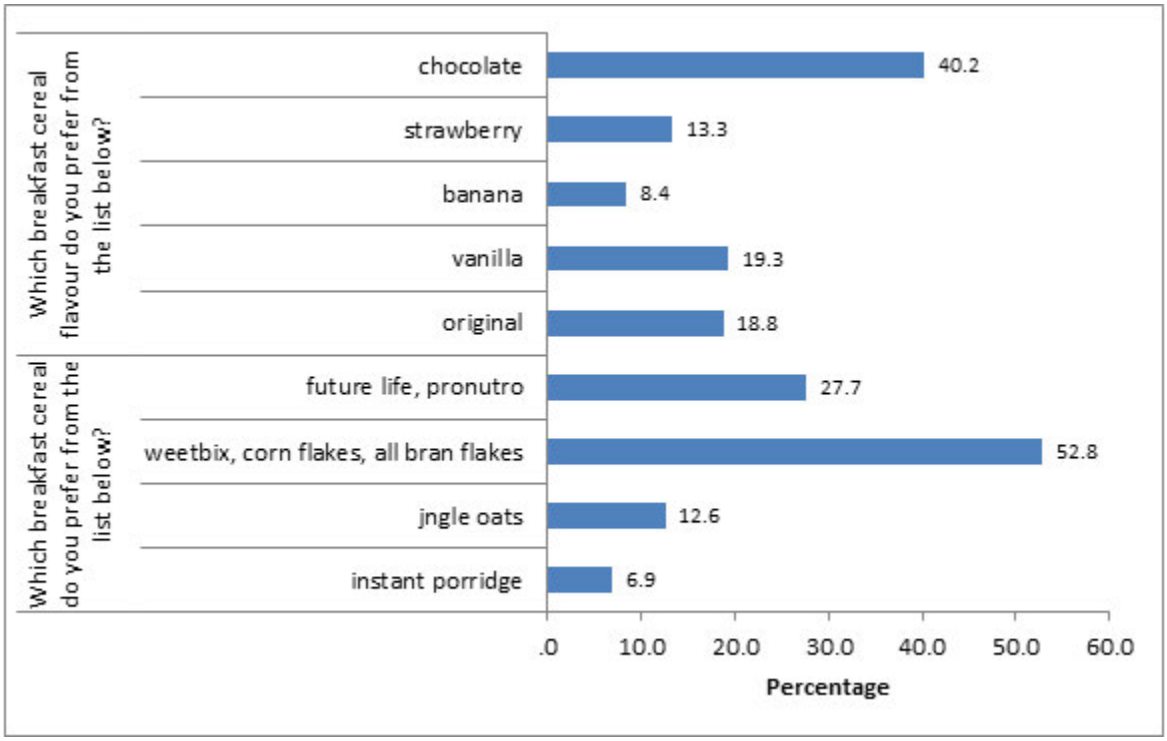


Figure 4. 13: Breakfast cereal names and flavour preference among school learners (n=405)

Figure 4.13 illustrates the preferences for breakfast cereal and flavour among school learners. The data indicates that 6.9% (n=28) of learners preferred instant porridge, 12.6% (n=51) favoured Jungle Oats, 52.8% (n=214) chose Weet-Bix, Cornflakes, and All Bran flakes, while 27.7% (n=112) preferred Future Life and ProNutro. Regarding flavour preference, 18.8% (n=76) of the learners preferred the original flavour, 19.3% (n=78) preferred vanilla, 8.4% (n=34) enjoyed banana, 13.3% (n=54) selected strawberry, and 40.2% (n=163) opted for chocolate.

Table 4. 4: Chi-square goodness-of-fit-test on the preferred breakfast cereal among learners (n=405)

Question 9	Responses as Frequency (%)				X^2	df	p-value
	Instant porridge	Jungle Oats	Weet-bix, Corn flakes, All bran	Future life, ProNutro			
Which breakfast cereal do you prefer from the list below?	28 (6.9)	51 (12.6)	**214 (52.8)**	**112 (27.7)**	204.630	3	<.001*

*indicates significance at the 95% level

Table 4.4 presents the Chi-square goodness-of-fit-test on the preferred breakfast cereal among learners. A significant proportion of the learners indicated that they preferred to consume Weet-bix, Cornflakes, All Bran Flakes (52.8%) or Future Life and ProNutro (27.7%) for breakfast p<.001.

Table 4. 5: Chi-square goodness-of-fit-test on the preferred breakfast cereal flavour among learners (n=405)

Question 10	Responses as Frequency (%)					X^2	df	p-value
	Original	Vanilla	Banana	Strawberry	Chocolate			
Which breakfast cereal flavour do you prefer from the list below?	76 (18.8)	78 (19.3)	34 (8.4)	54 (13.3)	**163 (40.2**)	119.704	4	<.001*

*indicates significance at the 95% level

Table 4.5 presents the Chi-square goodness-of-fit test on learners' preferred breakfast cereal flavour. A significant percentage (40.2%) of the learners indicated that they preferred a chocolate-flavoured breakfast cereal $p<0.001$.

4.3 Product development process

Objective 2 was to develop a nutritious and cost-effective breakfast cereal as determined by the results of the breakfast needs assessment and preference survey. Three trials were conducted, and the final product was a chocolate-flavoured instant porridge.

4.3.1 Fermentation of sorghum

To begin the product development process, the sorghum was fermented to increase the bioaccessibility of minerals; Figure 4.14 illustrates the changes in pH during the fermentation of sorghum.

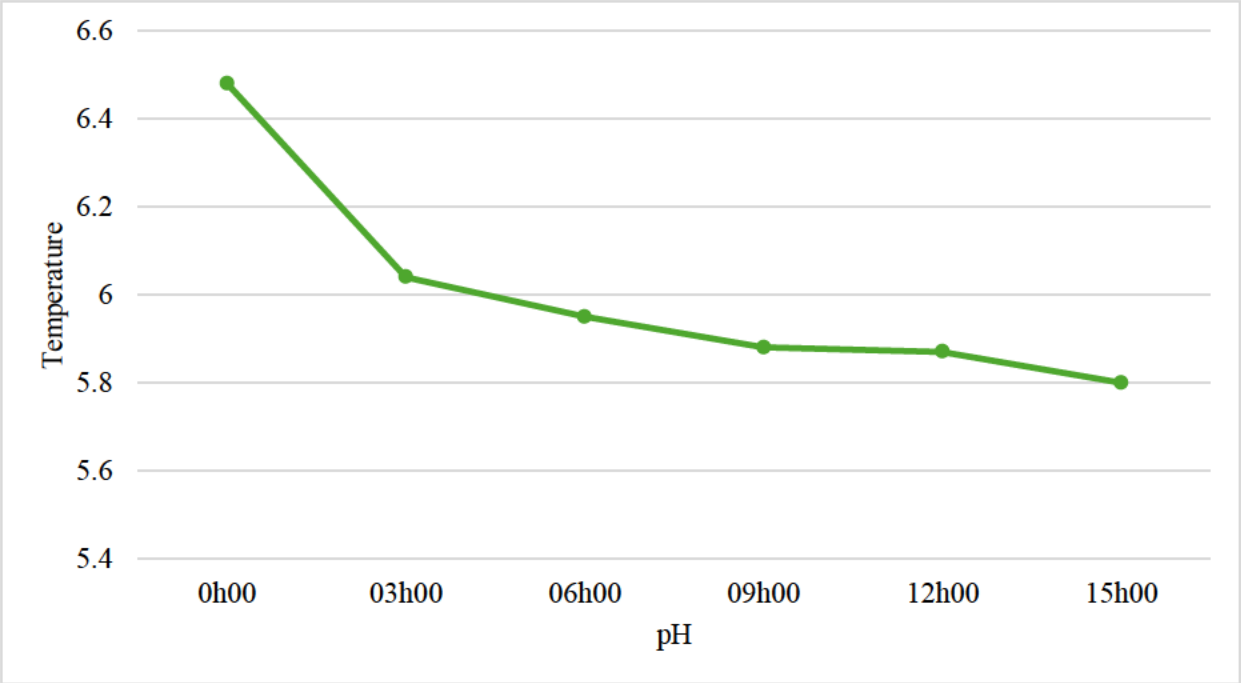


Figure 4. 14: pH changes during fermentation of sorghum

The experimental data for the change in pH of sorghum during fermentation is presented in the form of a graph, Figure 4.14, showing a progressive acidic pH after 15 hours at 37°C. The sample's initial pH was 6.48 before the start of fermentation (0h00) and steadily decreased to 6.04 at 3h00, indicating that fermentation is likely in its early stages when organic acid is produced. During

fermentation, the pH dropped further to 5.95 by 6h00, 5.88 by 9h00, and finally, a steady pH of 5.80 by 15h00. This pattern also suggests a gradual increase in acidity, which might be linked to the production of lactic acid, which is a result of fermentation.

4.3.2 Recipe formulation

The instant porridge was formulated using a 1:1 ratio of fermented sorghum and pearl millet. Several ingredients were added to provide a certain balance between nutritional and sensory characteristics. The instant porridge formulation is presented in Table 4.6.

Table 4. 6: Sorghum and pearl millet-based instant porridge recipe formulation

	Trial 1		**Trial 2**		**Trial 3**	
Ingredient	**Quantity (g)**	**Percentage (%)**	**Quantity (g)**	**Percentage (%)**	**Quantity (g)**	**Percentage (%)**
Starter culture	15	3.55	15	3.28	15	3.49
Red sorghum flour	150	35.47	150	32.84	150	34.93
Pearl millet flour	150	35.47	150	32.84	150	34.93
Cocoa powder	30	7.08	22.5	4.93	15	3.49
Milk powder	30	7.08	30	6.56	30	6.98
Fat powder	0	0	9	1.97	9	2.09
Brown sugar	45	10.63	60	13.14	90	20.95
Salt	3	0.71	3	0.66	3	0.70
Vanilla essence	6	1.42	6	1.31	6	1.40
Sillica dioxide	4	0.95	4	0.88	4	0.93
Total	423	100%	457	100%	429.5	100%

4.3.3. Preparation methods

A nutritious and sensory acceptable instant powder was developed over three trials. The various preparation methods utilised in the product development process are presented in Table 4.7.

Table 4. 7: Methods used to prepare the sorghum and pearl millet-based instant porridge

Method	**Trial 1**	**Trial 2**	**Trial 3**
1.	Place sterilised distilled water in a saucepan and bring to a boil	Same as trial 1	Same as trial 1
2.	In a bowl, mix sterilised distilled water with the fermented sorghum, pearl millet, cocoa powder, brown sugar and salt, stirring well with a balloon whisk to remove any lumps.	In a bowl, mix sterilised distilled water with the fermented sorghum, pearl millet, cocoa powder, milk powder, fat powder, brown sugar and salt, stirring well with a balloon whisk to remove any lumps.	Same as trial 2
3.	Gradually add the mixture to the boiling water, stirring continuously until the porridge begins to thicken slightly.	Same as trial 1	Same as trial 1
4.	Cover and simmer over medium heat for 30 minutes, stirring occasionally with a wooden spoon. Add vanilla essence and stir before removing from the stove.	Same as trial 1	Same as trial 1
5.	Preheat the oven dryer to 60°C. Pour and evenly spread the porridge into a thin layer on a tray that is lined with foil and greased with cooking spray. Dry the porridge in the oven at 60°C for 24 hours.	Same as trial 1	Same as trial 1
6.	Utilise the hammer mill to grind the dried porridge into a fine powder and add silica dioxide into the porridge	Same as trial 1	Same as trial 1
7.	Package instant porridge into airtight polyethylene packaging.	Same as trial 1	Same as trial 1

Tables 4.6 and 4.7 show the formulation and preparation technique that was followed in the development of the instant sorghum and pearl millet-based porridge through three trials where formulation changes were made depending on the result of the sensory assessment conducted at the end of the trial.

The ingredients used in each trial are listed in Table 4.6. A core formula was established by using a starting culture, red sorghum flour, and pearl millet flour consistently throughout all formulation trials. However, the feedback from consumer sensory assessments is reflected in the variability of other ingredients. For instance, in trial 3, the cocoa powder was decreased from the 30g used in trials 1 and 2 to 22.5g because the sensory assessment feedback reflected that the chocolate flavour was strong and overpowering. In contrast, the amount of brown sugar was increased from 45g to 90g, reflecting the shift in customer preferences towards a sweeter porridge. Additionally, based on the sensory assessment, the fat powder was included in trials 2 and 3 in an effort to improve the mouthfeel of the instant porridge.

Furthermore, table 4.7 outlines the methods used to cook the instant porridge: these were the same for all trials, although slight variations were made during the mixing process. In addition to this, milk and fat powder were added in trial 2 to address the consumer sensory assessment feedback regarding the texture and flavour of the formulated porridge. Boiling, simmering, and drying are the primary methods of preparation, and all three trials show that careful adherence to a standard method was maintained to ensure consistency in the final results.

In summary, the development process follows a systematic approach with sensory assessments guiding each trial to optimise product quality and consumer acceptability. The continuous enhancement of the formulation of the instant porridge is essential to ensure that the final product aligns with customer preferences, thereby enhancing the market viability.

4.3.5 Costing of ingredients

The cost-effectiveness of the instant porridge was assessed by calculating the total cost of ingredients used to develop the instant porridge.

Table 4. 8: Costing of the final sorghum and millet instant breakfast porridge

INGREDIENT	**QUANTITY (KG/L)**	**COST PER KG /L (EXCL VAT)**	**QUANTITY COST (EXCL VAT)**
Sodium benzoate powder	0.003kg	R105.00/kg	R0.32
Red sorghum	0.15kg	R18.99/kg	R2.84
Pearl millet	0.15kg	R29.99/kg	R4.50
Distilled water	0.8L	R219.61/25L	R7.02
Milk powder	0.03kg	R50.00/0.5kg	R3.00
Fat powder	0.009kg	R1510/20kg	R0.68
Cocoa powder	0.015	R75.99/kg	R1.14
Salt	0.003kg	R16.69/kg	R0.06
Soft brown sugar	0.015kg	R169.95/10kg	R0.25
Vanilla essence	0.01kg	R65.45/L	R0.65
Silicon dioxide	0.003kg	R311.00/kg	R0.93
Total cost	**0.388 kg**		**R21,39**
Cost per unit	**0.388/0.05 =7.76**		**R21.39/ 7.76 =R2.76**

Table 4.8 outlines the cost of the ingredients for the final developed product. Online food prices of large food retail and speciality stores were utilised to calculate the cost of ingredients of the sorghum and millet instant breakfast porridge. The cost of ingredients for 50g (recommended serving size) was R2.76.

4.4 Nutritional analysis

Objective 3 was to determine the amounts of macro- and micronutrients by means of nutrient analysis using the AOAC referenced methods.

Table 4. 9: Nutrient comparison of a sorghum and pearl millet instant porridge and DRI values (IOM 2005) for males and females aged 7-20 per 50g serving of instant porridge.

	Recommended Dietary Intake								
Nutrient	**Instant porridge (per 50g serving size)**	**4-8 years old**		**9-13 years old**		**14-18 years old**		**19-30 years old**	
		DRI	**% of DRI**	**DRI**	**% of DRI**	**DRI**	**% of DRI**	**DRI**	**% of DRI**
Males									
Macronutrients									
Protein (g)	5.05	19	26.58	34	14.82	52	9.71	56	9.02
Carbohydrate	34.8	130	26.77	130	26.77	130	26.77	130	26.77
Dietary fibre (g)	2.9	25	11.6	31	9.35	38	7.63	38	7.63
Total fat (g)	3.29	25-35	9.4-13.16	25-35	9.4-13.16	25-35	9.4-13.16	20-35	9.4-13.16
Micronutrients									
Sodium (g)	0.2575	1.2	21.46	1.5	17.17	1.5	17.17	1.5	17.17
Copper (Nu) (mg)	0.103	440	0.02	700	0.01	890	0.01	900	0.01
Iron (Fe) (mg)	1.904	10	19.04	8	23	11	17	8	23
Potassium (K) (g)	0.009	3.8	0.23	4.5	0.2	4.7	0.19	4.7	0.19
Magnesium (Mg) (mg)	0.206	130	0.158	240	0.085	410	0.050	400	0.051
Manganese (Mn) (mg)	0.184	1.5	12.27	1.9	9.68	2.2	0.36	2.3	8

Phosphorus (P) (mg)	1.575	500	0.315	1250	0.126	1250	0.126	700	0.225
Zinc (Zn) (mg)	0.619	5	12.38	8	7.73	11	5.63	11	5.63
Vitamin B1 (Thiamine) (mg)	0.185	0.6	30.83	0.9	20.56	1.2	15.42	1.2	15.42
Vitamin B3 (Niacin) (mg)	8.23	8	102.88	12	68.58	16	51.44	16	51.44
Females									
Macronutrients									
Protein (g)	5.05	19	53.16	34	29.71	46	21.95	46	21.95
Carbohydrate	34.8	130	26.77	130	26.77	130	26.77	130	26.77
Dietary fibre (g)	2.9	25	34.52	26	25.89	26	23.02	25	20.71
Total fat (g)	3.29	25-35	9.4-13.16	25-35	9.4-13.16	25-35	9.4-13.16	20-35	9.4-13.16
Sodium (mg)	0.103	1.2	27.11	1.5	23.41	1.5	22.39	1.5	22/38
Micronutrients									
Copper (Nu) (mg)	0.103	440	0.02	700	0.01	890	0.01	900	0.01
Iron (Fe) (mg)	1.904	10	19.04	8	23.8	15	12.69	18	10.58
Potassium (K) (g)	0.009	3.8	0.23	4.5	0.2	4.7	0.19	4.7	0.19
Magnesium (Mg) (mg)	0.206	130	0.158	240	0.085	360	0.057	310	0.66
Manganese (Mn) (mg)	0.184	1.5	12.27	1.6	11.5	1.6	11.5	1.8	10.22
Phosphorus (P) (mg)	1.575	500	0.315	1250	0.126	1250	0.126	700	0.225
Zinc (Zn) (mg)	0.619	5	12.38	8	7.73	9	6.87	8	773
Vitamin B1 (Thiamine) (mg)	0.185	0.6	30.83	0.9	20.56	1.0	18.5	1.1	16.82
Vitamin B3 (Niacin) (mg)	8.23	8	102.88	12	68.58	14	58.79	14	58.79

The nutritional composition of a sorghum and pearl millet instant porridge against the recommended dietary intake values for males and females aged 7-2 (Medicine 2005) are presented in Table 4.9 at a serving size of 50 grams. The results for males 4 to 8 years of age revealed that the instant porridge contributes 26.58% of the DRI for protein, which is a good amount for this age, in addition to 34.8% of the amount of carbohydrate that the body needs. Dietary fibre per serving was calculated to be 11.6g, accounting for 38% of the recommended fibre requirement. The total fat content is consistent across all age ranges for both boys and girls, with a range of 9.4-13.16%. The percentage contribution of sodium remains commendable at 21.46% DRI and is likely to attract the interest of parents seeking to establish low sodium intake among children. Furthermore, the porridge has a high iron content, thus it contains 1904% DRI for the age group of 4-8 years.

For females between the ages of 4-8 years, the porridge proved to be equally nutritional, with a DRI for protein at 53.16% and a dietary fibre content of 34.52%. The sodium content for females is measured at 0.2575g (27.11% of the DRI), which is slightly lower compared to males. Furthermore, the porridge is exceptionally rich in iron and provides a surprising 19.04% of the DRI for iron for younger females, indicating a good contribution to the nutrition of growing girls.

Males and females between the ages of 9 and 30 years obtain various contributions to their DRI as presented above; however, the degree of contribution declines according to age. Regarding protein, males in the 9-13 years age group receive 14.82% DRI from the instant porridge; this is a good source contributing to bodily growth and muscle mass during this important developmental stage. The percentage of carbohydrates in the suggested serving size is still relatively high at 26.77%, showing that it is a good source of energy, especially for teenagers. Equally important is the intake of dietary fibre, which ensures a healthy digestion system, providing 9.35% of the DRI for this age group.

With an increase in age to 14-18 years, the males received 9.71% and fibre 7.63% of protein and fibre DRI, respectively, from the breakfast porridge. Interestingly, the DRI and the percentage that the porridge provides for males under 19 and between 19 to 30 years remain constant for carbohydrates, dietary fibre, fat and sodium to maintain their young, energy-requiring bodies.

For females, the contribution of protein remains significant, especially in the 9-13 years age group (29.71% of DRI), and remains the same for 14-30 year olds (21.95 % of the DRI). Moreover, the porridge contributes approximately 26.77% of the carbohydrate DRI across all age groups. In contrast, the dietary fibre percentage remains relevant, culminating in 23.02% of the DRI for females aged 14-18 and 20.71% for females aged 19-30 years.

Furthermore, the results in Table 4.9 illustrate that the instant porridge is exceptionally rich in vitamins and minerals. For example, the instant porridge contributes more than 10% of the DRI for iron and manganese for all age groups, making it a very nutrient-dense breakfast option. Moreover, the instant porridge contributes moderate quantities of zinc across all age groups. In contrast, copper, magnesium, phosphorus and potassium have lower DRI coverage rates across all age groups, showing that the instant porridge needs further improvements, although it contains high quantities of certain nutrients.

Additionally, the instant porridge contributes an impressive proportion of vitamin B3, particularly among young men and females aged 4 to 8 and 9 to 13, with contributions of 102.88% and 68.58% of the DRI, respectively. Similarly, the percentage contribution of vitamin B1 is very high in all age groups, with the highest proportion of 31.67% among males between the ages of 4 to 8 years. This shows that the porridge has the potential to enhance the metabolism and energy production of school learners.

Table 4. 10: Nutritional comparison of a sorghum and pearl millet instant powder compared to competitors

Nutrient	**Sorghum and pearl millet instant porridge (per 100g)**	**Ace Instant (per 100g)**	**MyLife (per 100g)**
Macronutrients			
Energy (kJ)	1645	1562	1602
Protein (g)	10.1	5.4	8.9
Carbohydrate (g)	69.6	82	57.2
Total fat (g)	6.57	1.5	5.1
Of which saturated fatty acids (g)	2.55	0.3	0.9
Of which monounsaturated fatty acids (g)	2.11		
Of which polyunsaturated fatty acids (g)	1.91		
Of which trans fatty acids (g)	0.02 g		
Of which omega-3 fatty acids (g)	0.106		
Of which omega-6 fatty acids (g)	1.8		
Cholesterol	0	0	0
Dietary fibre (g)	5.8	2.3	7.9
Total sodium (mg)	515	197	516

Vitamins			
Vitamin B1 (Thiamine) (mg)	0.185	0.7	
Vitamin B2 (Riboflavin) (mg)	<0.00	0.4	
Vitamin B3 (Niacin) (mg)	8.23	10.8	
Vitamin B5 (Pantothenic acid) (mg)	<0.03	0.7	
Minerals			
Copper (Nu) (mg)	0.103		
Iron (Fe) (mg)	1.904		
Potassium (K) (mg)	0.009		
Magnesium (Mg) (mg)	0.206		
Manganese (Mn) (mg)	0.184		
Phosphorus (P) (mg)	1.575		
Zinc (Zn) (mg)	0.619		

The nutritional composition per 100g of three different brands of instant porridge—MyLife, Ace instant porridge, and the sorghum and pearl millet porridge is thoroughly compared in Table 4.10. Tiger Brands Foundation sponsors Ace instant porridge in various NSNP schools. MyLife was chosen since it is the cereal that is currently served for the NSNP breakfast in the primary schools that participated in the current study.

Sorghum and pearl millet-based porridge contain the highest energy value of 1645 kJ, followed by MyLife with 1602 kJ and Ace with 1562 kJ. Regarding protein content, the sorghum and pearl millet porridge has the highest value of 10.1 g, followed by MyLife with 8.9g and Ace with 5.4, which indicates that the developed porridge has a higher protein content.

However, Ace has a much higher carbohydrate content (82g) compared to MyLife (57.2 g) and the sorghum and pearl millet instant porridge (69.6 g). Along with having the greatest total fat content (6.57 g), sorghum and pearl millet also have the highest percentage of monounsaturated and polyunsaturated fatty acids. However, it contains an insignificant quantity of trans-fatty acids (0.02 g), a proportion that is absent from the other two products. In terms of dietary fibre, Ace has a lower fibre content of 2.3g, whereas the sorghum, pearl millet, and MyLife have comparable quantities at 5.8g and 7.9g, respectively.

Moreover, all three competitors have very low cholesterol levels. Additionally, the sorghum and pearl millet instant porridge has considerably higher sodium levels (515 mg), comparable to MyLife's 516 mg. However, Ace has significantly lower amounts (197 mg).

In terms of vitamin content, the sorghum and pearl millet porridge contains a competitive 8.23mg of B2 compared to 10.8mg from Ace. However, the sorghum and pearl millet porridge has insignificant quantities of B1 and B3 and B5 compared to Ace. Regarding the mineral content, the sorghum and pearl millet porridge contains significant amounts of iron (1.904 mg) and phosphorus (1.575 mg), which are not found in the other two products. Overall, Tables 4.9 and 4.10 highlights that the sorghum and pearl millet instant porridge is rich in protein, fibre, and specific minerals, making it a potentially beneficial option to enhance the dietary intake of learners that receive the NSNP breakfast.

4.5 Microbiological quality

According to the fourth objective, microbiological quality test of a freshly produced breakfast porridge was conducted in a SANAS accredited laboratory using AOAC methods. A coliform bacteria count, total aerobic plate count and yeast and mould test was used to determine if there were harmful micro-organisms present in the product.

Table 4. 11: Results of the microbiological testing of the freshly prepared sorghum and pearl millet instant porridge

	Permitted number of colonies/g	Number of colonies present in sample/g	Legislation compliance status
Coliform bacteria	10^4	<1	Compliant
Total aerobic bacteria	10^6	<10	Compliant
Yeast and mould	10^4	<1	Compliant

Table 4.11 displays microbial characteristics of the freshly produced sorghum and pearl millet instant porridge, including coliform bacteria, total aerobic bacteria count, yeast, and mould, compared to food regulations' regulatory limits, with actual counts and compliance status data. Coliform, total bacteria, yeast and mould counts were very low and well within the acceptable range. The results are in accordance with the Foodstuffs, Cosmetics and Disinfectants Act, and regulations governing microbiological standards for foodstuffs and related matters (SA DOH 2008).

4.6 Shelf-life analysis

A shelf-life test was performed to meet the fifth objective, which was to assess the microbiological stability of the sorghum and pearl millet-based instant porridge after 12 days of accelerated shelf-life testing at 35°C, which is approximately equal to 12 weeks of storage at room temperature (18-25°C) in properly sealed packets. The microbiological testing was done in compliance with the specifications of the Foodstuffs, Cosmetics and Disinfectants Act, Regulation of microbiological standard for foodstuffs and everything

related to it (SA DOH 2008). According to Tarlak (2023), the knowledge of microbiological patterns is paramount when evaluating the safety and the quality of food products during their shelf life. The following results were obtained for the porridge sample after the specified storage condition:

Table 4. 12: Microbiological testing of the sorghum and pearl millet instant porridge after accelerated shelf-life testing.

	Permitted number of colonies/g	Number of colonies present in sample/g	Legislation compliance status
Coliform bacteria	10^4	<1	Compliant
Total aerobic bacteria	10^6	<10	Compliant
Yeast and mould	10^4	100	Compliant

Table 4.12 displays microbiological testing results for sorghum and pearl millet-based instant porridge after 12 days of accelerated shelf-life testing at 35°C, including counts of aerobic bacteria, yeast and moulds, and compliance status. The microbiological counts indicated that the breakfast porridge has a stable shelf life. There was no significant increase in microbial numbers. Physical and sensory tests indicated that no product deterioration was observed in terms of moisture hygroscopicity, colour or odour. Shelf-life estimation is one year under cool storage conditions (15°C to 25°C).

4.7 Learner sensory assessment

The sensory assessment covers the sixth objective which was to conduct sensory assessment to establish the acceptability and palatability of the developed product. The researcher utilised a validated 7-point hedonic scale (ranged from 1=Super bad to 7= Super good) to conduct the sensory assessment. A sample of 200 learners was recruited for the sensory evaluation of the breakfast porridge.

4.7.1 Demographics

The demographic profile of the learners from each of the four geographic areas includes gender, age, and grade.

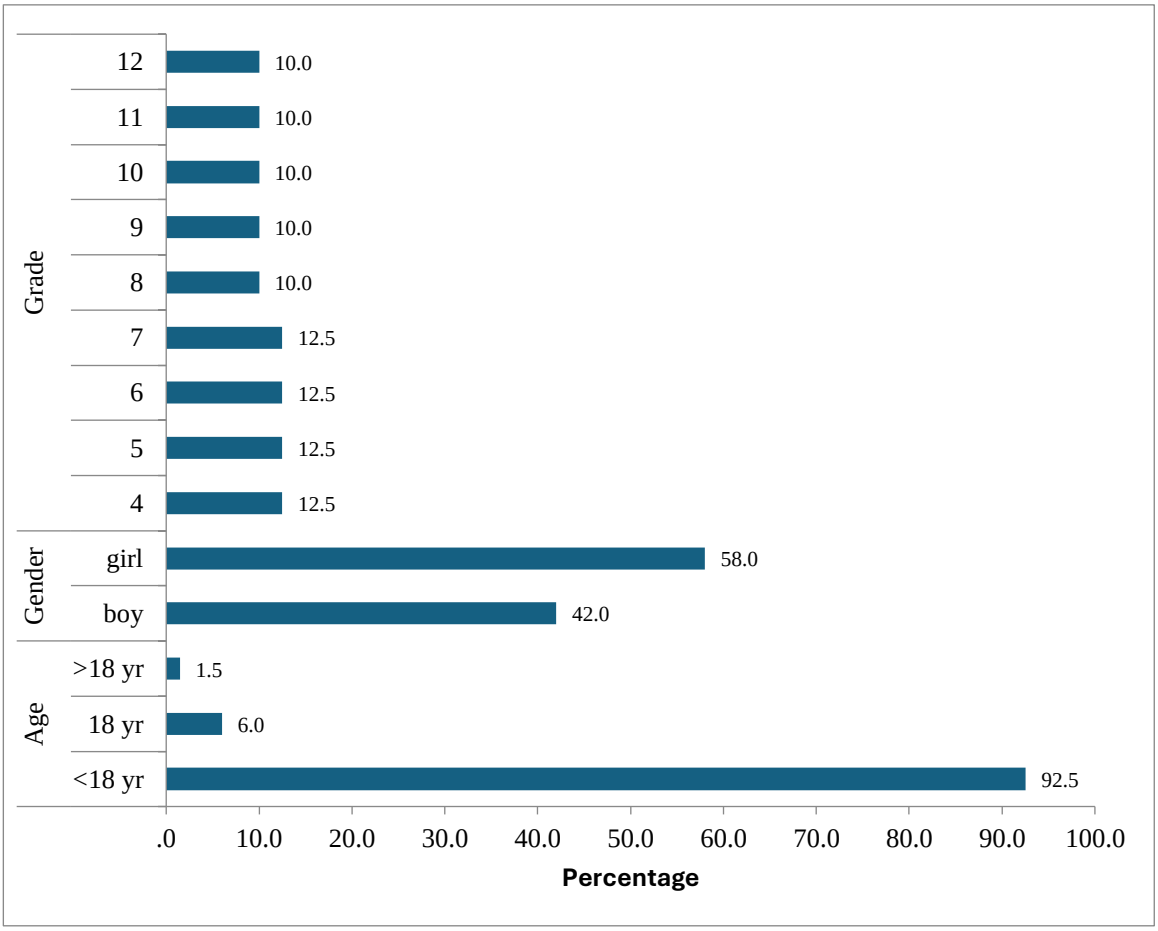
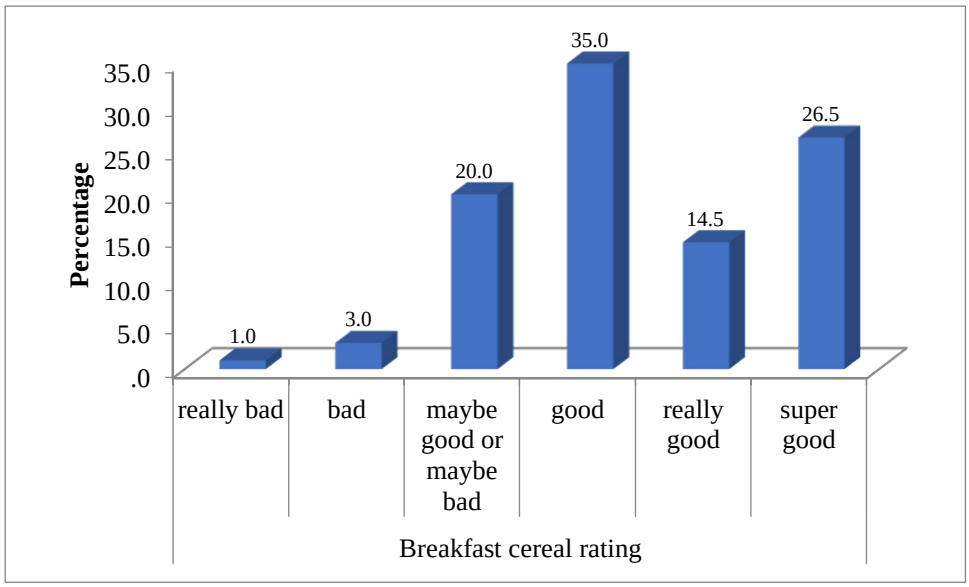


Figure 4. 15: A display of the demographic profile of school learners that participated in the sensory assessment (n=200)

Figure 4.16 depicts the demographic profile of school learners that participated in the sensory evaluation of the breakfast porridge (n=200), of which 92.5% (n= 185) were below the age of 18, 6.0% (n= 12) were 18 years old, and 1.5% (n= 3) were above the age of 18. Regarding gender, 42.0% (n=84) of the participants were males, whereas 58.0% (n=116) were females. Regarding the school grade, 12.5% (n=25) of the participants were from grade 4, 12.5% (n=25) from grade 5, 12.5% (n=25) from grade 6, and 12.5% (n=25) from grade 7. Furthermore, 12.5% (n=25) of the participants were from grade 8, 12.5% (n=25) from grade 9, 12.5% (n=25) from grade 10, 12.5% (n=25) from grade 11, and 12.5% (n=25) were from grade 12.

4.7.2 Sensory acceptance and palatability



A display of the breakfast cereal rating (n=200)

Figure 4. 16: depicts the breakfast cereal rating among learners. When compared to a rating of 3 (neutral), a significant proportion of the learners rated the cereal higher than 3 (good to super good), p<0.001. Conversely, only a small proportion (4.0% [1.0% + 3.0%]) had a distinctly unfavourable impression of the cereal. A considerable number of learners (20.0%) expressed ambiguity (maybe good or maybe bad) regarding the cereal's sensory appeal.

Table 4. 13: Independent sample t-test on the breakfast cereal rating (n=200)

Category	n	Mean (SD)	t	df	p-value
Boy	84	4.70	3.219	198	<.002*
Girl	116	4.16			

*indicates significance at the 95% level

Table 4.13 presents the independent sample t-test on the breakfast cereal rating. While both boys and girls rated the cereal above 4, on average, boys (mean = 4.7) rated it significantly higher than girls (mean = 4.16), t (198) = 3.219, p=0.002.

4.8 Discussion

4.8.1 Learner needs and preferences for breakfast provisioning

Consuming breakfast regularly is associated with adequate macro- and micronutrient intake (Moreno-Aznar *et al.* 2021b), cognitive performance (Massomi *et al.* 2020) and improved food choices later in life (Souza 2023). In addition, children and adolescents (aged 2–20 years) are more likely to be overweight and obese if they do not eat breakfast (Wang *et al*. 2023).

This study investigated breakfast needs and preferences among a wide sample of grade 4–12 learners (aged 7–20 years) in KZN, iLembe district. The learners who participated in the breakfast needs and preference survey were selected in equal proportions from primary and secondary schools from quintile 1, 2 and 3 schools in rural and semi-urban areas. The learners that participated in the survey were selected from four schools implementing the NSNP, and the learners' geographical distribution was diverse; thus, it can be concluded that the study findings can be extended to schools implementing this programme across the country. Nonetheless, while the extension of NSNP in 2024 to ECD centres and quintile 4-5 schools confirms its expansion, these schools were not captured in this study due to the expansion taking effect midway through the study.

Encouragingly, 35.1% of the learners consumed breakfast before coming to school. However, 49.9% of the learners reported skipping breakfast sometimes, and 15.1% skipped breakfast daily. The prevalence of breakfast skipping reported in the current study is in line with international evidence. A systematic review of 39 studies, including 285,626 children aged 2–18 years across 33 countries, reported that between 10–30% of children and adolescents skipped breakfast (Monzani *et al.* 2019).

However, the findings of the current study indicate that there is lower consumption of breakfast among learners attending lower-quintile schools compared to higher-quintile schools. For instance, Hansena *et al.* (2022) reported that 81.6% of quintile 5, Free State province primary school learners consumed breakfast daily. Similarly, 81% of quintile 1-5 high school learners consumed breakfast in the North West province (Tee, Botha and Jerling 2015).

Furthermore, the results from this study indicated that learners do not consume breakfast because they do not have time to eat (56.7%). School learners in rural and semi-rural schools may also face longer commute times to school in the morning, adding additional time constraints (Hearst *et al.* 2016).

According to the study findings, another perceived barrier to consuming breakfast among school learners is not having enough food (30.0%). This highlights the prevalence of food insecurity at the household level. According to Stats SA (2021), 15 percent (2,6 million) of households have inadequate access to food, whereas 6 percent (1,1 million) have severely inadequate access to food. Given the identified benefits of

breakfast, and the prevalence of breakfast skipping among school learners in the iLembe district, the provision of a breakfast meal is important in this target group.

Other reasons for skipping breakfast (2.3%) in the study findings include not being hungry in the morning, waking up to load shedding, trying to lose weight and stomach cramps. Similarly, results from a study conducted in Ethiopia by Feye *et al.* (2023), show that learners skip breakfast because of poor appetite in the morning (35.7) and 13% due to body image/shape concerns. Likewise, not feeling hungry (60%) and the desire to lose weight (15%) were some of the reasons for skipping breakfast in a study conducted by Badrasawi, Anabtawi and Al-Zain (2021) in Palestine. Breakfast skipping is not an effective strategy for losing weight. It has been associated with a high risk of being overweight or obese, cardiometabolic risks, and unhealthy diet regimens among both children and adults (Ricotti *et al.* 2021).

Ready-to-eat breakfast (RTE) cereals were the most frequently consumed breakfast cereals by 26.83% of the learners, followed by bread by 21.51%, leftovers by 8.65% and other relevant breakfast foods. Tee, Botha and Jerling (2015) reported that bread, RTE-eat cereals, and porridge were the most frequently consumed foods in the morning. In the present study, learners reported that they consumed porridge (11.09%), followed by Cornflakes (9.09%), Weet-Bix biscuits (2.44%), and Jungle oats (2%). Similarly, another study conducted by Hansena *et al.* (2022) revealed that quintile 5 school learners in Bloemfontein consumed RTE-eat breakfast cereals: Weet-Bix (51.4%), Corn Flakes (44.8%), and oats (44.1%) were rated as the most popular choices. It is noteworthy that porridge was chosen as the most preferred breakfast cereal among quintile 1-3 school learners, while no porridge was reported by learners in Quintile 5 schools. (Dlamini *et al.* 2023b) also confirm that most households in rural (21.3%) and peri-urban (21.5%) areas had a higher food insecurity rate (17.5%) than households in urban areas. Learners in this current study, therefore, consumed more porridge than learners in the study conducted among urban school students due to their parents' inability to purchase extruded breakfast cereals due to the prevalence of household food insecurity.

RTE breakfast cereals are popular among school children mostly because of the convenience they provide for working and busy families (Frimpong, Wireko-Manu and Oduro 2022). Such cereals are preferred by many parents who want their children to have a quick, tasty meal before they go to school (Anusha *et al.* 2020). Moreover, the particular brands selected by the learners are often influenced by peer pressure from friends since learners aspire to consume the breakfast cereals that their peers consume (Landwehr and Hartmann 2024).

Marketing communication also contributes immensely towards the school children's choice of breakfast (De Veirman, Hudders and Nelson 2019). Most cereals have colourful and stimulating television

advertisement clips with characters known and admired by young children (Pombo-Rodrigues *et al.* 2020). This strategy not only makes the cereals seem suitable for children but also makes them wanted by children. In addition, some brands have also made their way into the schools through promotions and sponsorships, therefore enhancing their accessibility and making the brands part of learners' daily lives, thus encouraging the consumption of RTE breakfast cereals (WHO and UNICEF 2023).

The second most preferred breakfast item was bread, where 21.51% of the learners indicated that they consumed it. Similarly, bread was considered a preferable breakfast item by school learners in the North West province (Tee, Botha and Jerling 2015). Bread is readily available and can be purchased from local spaza shops in rural and semi-urban areas (O'Halloran *et al.* 2021). Furthermore, bread can be consumed with various fillings to accommodate various flavour preferences. Moreover, margarine was the most popular spread among the school learners who ate bread for breakfast (6.65%), followed by polony as a filling (3.99%). Margarine and polony have gained consumer appeal because they are affordable, have an extended shelf-life, and take little time and effort to incorporate into meals. According to Silva, Barrera-Arellano and Ribeiro (2021), among all spreads, margarine is very popular among consumers as it is perceived as a healthier and affordable alternative to butter. However, the regular intake of processed meats increases the cases of type 2 diabetes, cardiovascular diseases, and colon cancer, implying the necessity for substitutes from plant sources for the best result (Qian *et al.* 2020).

Furthermore, the findings of the current study also showed that learners preferred pairing their breakfast with tea, with 7.89% (n=36) choosing tea. Valavanidis (2019) states that tea is the most popular beverage globally. Moreover, the most common reason that emerged from the study conducted in Bloemfontein by Hansena *et al.* (2022) was that most guardians prepared tea for their children (29.6%) to enjoy with the breakfast meal. This demonstrates that their guardians' preferences influence the breakfast choices available for school children.

Moreover, the study findings indicate that 52.8% of learners prefer to eat Weet-Bix, Corn Flakes, and All Bran flakes, while 27.7% prefer Future Life and ProNutro, 12.6% prefer Jungle oats, and 6.9% prefer to eat instant porridge as the NSNP breakfast meal. Despite being a source of extra sugar and thus a health issue, RTE cereals have gained popularity as a breakfast choice and claim to offer vital nutrients to children's diets (Santos *et al.* 2021). South Africa is undergoing a unique nutrition transition due to economic globalisation, urbanisation, income, and westernisation of foods (Gupta, Kapur and Dietetics 2017; Nel, Steyn and Health 2022). This change impacts school learners' food and dietary behaviours and increases the consumption of processed and convenience foods, particularly RTE breakfast cereals (Gupta, Kapur and Dietetics 2017; Nel, Steyn and Health 2022). This may lead to the emergence of obesity and NCDs among school learners (Gupta, Kapur and Dietetics 2017) One way in which this gap may be closed is through the NSNP's

provision of wholegrain breakfast cereal to all schools. Furthermore, education plays an important role; therefore, conducting nutrition education programmes in relation to regular breakfast taking and balanced diets can help manage negative tendencies associated with nutrition transition.

Additionally, when asked which flavour they preferred, a significant 40.2% of school learners stated that they would like to eat a chocolate-flavoured morning cereal as part of the NSNP. Although chocolate is a luxury and an indulgent treat that is enjoyed all over the world (Del Prete and Samoggia 2020), it is important to make sure that the developed RTE porridge is nutritionally balanced, includes whole grains and has less sugar to encourage better eating practices among school learners (Santos *et al.* 2021). This presents an excellent chance to innovate a chocolate-flavoured sorghum and pearl millet-based instant porridge to align consumption with health benefits, hence encouraging a healthier eating culture within student circles. According to (Tshisikhawe, Runhare and Litshani 2024) incorporating flavours that school learners desire into school nutrition programmes increases their effectiveness and enjoyment.

4.8.2 Nutritional quality and potential health benefits of the sorghum and pearl millet-based instant porridge

Breakfast is an important source of key nutrients in the diet (Giménez-Legarre *et al.* 2020). According to Savarino, Corsello and Corsello (2021), school learners require an adequate intake of micronutrients and macronutrients to ensure optimum growth (Savarino, Corsello and Corsello 2021). A breakfast meal should provide approximately a third of a child's daily requirements (Valizadeh, Ng and Biology 2020). Thus, the nutritional composition of the sorghum and pearl millet-based instant porridge was analysed in relation to DRI for school learners. The nutritional composition of the sorghum and pearl millet-based instant porridge meets and frequently surpasses 30% of the RDI for school-age children, as demonstrated by the comparison of the nutritional composition of the instant porridge made from sorghum and pearl millet (refer to Table 4.9).

The sorghum and pearl millet-based instant porridge contains a high percentage of the DRI for protein, essential for muscle growth and development, especially for school learners who participate in physical activities (Carbone and Pasiakos 2019). In addition, the quality of carbohydrates in the instant porridge provides assurance that school learners will be provided with energy that will help them to stay active and focused throughout the morning up to lunchtime (Hantzidiamantis, Awosika and Lappin 2024). Moreover, the increased dietary fibre intake helps regulate digestion, protects against intestinal disorders and ensures long-term satiety, which is important for weight management during the development phases (Ioniță-Mîndrican *et al.* 2022).

Vitamins and minerals are essential to humans as they play essential roles in various basic metabolic pathways that support fundamental cellular functions (Tardy *et al.* 2020). The developed instant porridge contains exceptional quantities of B3, B1, and manganese. Vitamin B1 is essential for the proper regulation of brain function, and vitamin B3 is important for the metabolism of macronutrients (Ullah, Rauf and Daglia 2024). Moreover, manganese plays an important role in the defence of organisms against oxidative stress (Martins *et al.* 2020).

Furthermore, the instant porridge contributes significant proportions of the RDI for various minerals, particularly iron and zinc. The impressive levels of iron and zinc result from the fermentation process. Fermentation increases the bioavailability of iron and zinc (Adeyanju *et al.* 2019). Iron is crucial for healthy red blood cells (Benson *et al.* 2021), while zinc is essential for immune function and protein synthesis (Dardenne and Bach 2020).

According to Malan *et al.* (2024), anaemia, iron and zinc deficiencies are still high in South Africa, especially among rural children from a low socio-economic background. A study conducted in KZN, South Africa, revealed that there is a high point prevalence of anaemia (23.4%), iron deficiency anaemia (4.9%) and helminth infection (27.1%) among children aged 6 to 8 years. Approximately 20.7% of the sampled children demonstrated low cognitive assessment scores (Gwetu *et al.* 2019). In addition, Motadi *et al.* (2023), also noted that 25 percent of 3 to 5-year-old pre-schoolers attending ECD centres in the Musina municipality of Venda in South Africa were deficient in iron. Moreover, the prevalence of anaemia, iron depletion, and iron-deficiency anaemia in South African adolescents (15- to 18-year-olds) was reported to be 11.2%, 8.8%, and 20.2%, respectively (Mchiza *et al.* 2018). Therefore, consuming the developed porridge may help combat the ongoing burden of deficiency diseases among school children.

Moreover, the developed instant porridge is of higher nutritional value when compared to the current NSNP breakfast offerings, namely Ace and MyLife instant porridge. For instance, the developed instant porridge has a higher protein and dietary fibre content than Ace and MyLife instant porridge. Furthermore, the developed instant porridge contains many minerals and B vitamins that may benefit the health of school learners. Additionally, the developed instant porridge contains omega-3 and omega-6 fatty acids to support learning (improved reading ability, spelling, behaviour, attention and reduced hyperactivity and aggression) among school learners. These nutrients may enhance concentration and memory among school learners, making the developed instant porridge a more suitable replacement to the current NSNP breakfast offerings.

In essence, the sorghum and pearl millet-based instant porridge is a nutritious, RTE breakfast meal that could enhance the school learners' academic performance, health and general welfare. The study by Mahmood *et al.* (2021) revealed that children who are fed nutrient-rich foods are likely to improve their

eating habits and possibly reduce the risk of contracting obesity and its realisations, such as Type 2 Diabetes Mellitus, in their adulthood. As a result, the nutritional value of the sorghum and pearl millet-based instant porridge makes it suitable for supplementing the DRI shortfall within the NSNP.

4.8.3 Cost-effectiveness of sorghum and millet-based porridge compared to other breakfast options

The sorghum and millet-based instant porridge, which costs R2.76 per 50g, has a total cost price of R27.80/0.5kg. According to Uddin and Yilmazkuday (2017), the mark-up estimation considers labour, capital, and intermediate inputs such as production components. All business expenditures are subtracted from total revenue to determine the net profit margin (Ramadhan and Nuraliati 2020). Therefore, given a 45% mark-up and a 5% profit margin, the selling price would be approximately R41.70/0.5kg. The selling price positions the developed instant porridge competitively within the RTE breakfast cereal market compared to ProNutro (R54.99/0.5 kg) and Future Life (R54.99/0.5kg). The developed instant cereal is also more cost-effective than the RTE breakfast cereals that the school learners would like to consume for breakfast from the NSNP based on findings from the breakfast needs assessment survey. For instance, Corn Flakes cost about R49.45/0.5kg, while All-Bran flakes and Weet-Bix cost R58.95/0.5kg and R34.75, respectively. Furthermore, providing the preferred RTE breakfast cereals will cost more because they are served with milk, which costs R13.95/L and requires refrigeration, whereas the developed instant porridge only requires clean, warm water to be reconstituted before serving. However, the developed instant cereal is more costly compared to Morvite (R34.99/kg), Tiger Brand's Ace instant porridge (R26.95/kg), and MyLife instant porridge (R14.99/0.5kg).

Overall, given its competitive price point compared to ProNutro, Future Life Corn Flakes, All-Bran flakes, and Weet-Bix, the sorghum and millet-based instant porridge not only offers an affordable alternative but also provides enhanced nutritional benefits, making it a value-added choice for the NSNP which seeks both cost-effectiveness and health advantages in their breakfast options.

4.8.4 Microbiological quality and safety compliance

The microbiological and accelerated shelf-life testing results for instant porridge indicate that instant porridge is safe for consumption. Food safety regulation standards were met due to the absence of coliform bacteria and the low count of total aerobic bacteria, yeast, and mould. This means that the porridge meets the safety standards required to protect the consumer and is thus not a health risk.

This was further confirmed by the less than one colony count obtained for coliform bacteria and the total aerobic bacteria from the microbiology and shelf-life test that was conducted on the instant porridge. This level of cleanliness is vital in making sure that products intended for young consumers, such as school-

going children in the school feeding programmes, are safe (FAO 2019a). However, an increase in the yeast and count mould was observed while conducting the shelf-life analysis; nevertheless, the maximum value of 100 colonies/g is within a permissible range according to legislation.

CHAPTER 5: CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

This chapter presents the study's conclusion and recommendations based on the findings covered in the preceding chapter. The strengths and limitations of the study are also discussed. This study aimed to develop a sensory acceptable, nutritious, and cost-effective breakfast porridge suitable for the NSNP to supplement the current meal provisioning of the NSNP.

5.2 Summary of main findings

Objective 1: To conduct a needs assessment for breakfast provisioning for learners by conducting a breakfast needs assessment and preference survey.

The breakfast needs and preference survey revealed that most learners consumed breakfast inconsistently, often skipping it due to lack of time or not having access to food. Primary school learners received porridge from the NSNP at school, which is usually sponsored by big food companies. Learners expressed a preference for Corn Flakes, All-Bran Flakes, or Weet-Bix as breakfast cereals, with chocolate being the most desired cereal flavour.

Objective 2: To develop a nutritious and cost-effective breakfast cereal using the steps of product development and to determine the nutrient content of the breakfast cereal through nutritional analysis.

The findings from the breakfast needs and preference survey informed the product development of a chocolate-flavoured sorghum and pearl millet instant porridge. The product development process involved controlled fermentation of the sorghum grain, and consumer sensory assessment was conducted to inform changes for the subsequent trials. Following the product development process, a sensory acceptable, nutritious, and cost-effective breakfast porridge suitable for the NSNP was developed.

The nutritional analysis reflected that the developed instant porridge was packed with protein and dietary fibre. It also contained high levels of zinc and iron, attributed to the fermentation of the sorghum grains and the incorporation of pearl millet into the recipe formulation. Vitamin B1 and B3 were not present in notable amounts. The instant porridge often met or exceeded the 30% of the recommended RDI that a breakfast meal should cover. The nutritional composition of the instant porridge is of higher nutritional value when compared to the current NSNP breakfast offerings, making it a more suitable and nutritious breakfast option to supplement the RDI shortfall within the NSNP and improve academic performance, health, and overall

welfare. Its nutritional value exceeds current breakfast offerings, making it a more suitable and nutritious option for school learners.

Objective 3: To determine the microbiological level and shelf-life stability of the breakfast cereal through microbiological tests and shelf-life analysis.

The instant porridge was tested for microbiological food safety and meets food safety regulations due to the absence of coliform bacteria and low counts of total aerobic bacteria, yeast, and mould. This ensures that the porridge meets consumer safety standards and is not a health risk. This is crucial for products intended for young consumers, like school-going children in school feeding programmes.

The accelerated shelf-life study revealed that the instant porridge has a 12-month shelf life. Its microbiological quality and shelf-life stability make it suitable for distribution and storage at schools implementing the NSNP. Proper storage and training of food distributors and handlers is recommended to maintain the product's quality. The instant porridge's shelf-life stability and microbiological safety enhance its health and wellness benefits.

Objective 4: To conduct a sensory evaluation survey to establish the acceptability and palatability of the breakfast cereal among learners in the NSNP.

The instant porridge was subjected to sensory assessment by school learners. The school learners evaluated the instant porridge using a seven-point facial hedonic rating scale with verbal anchors. The sensory acceptability score was higher among boys compared to girls. Nevertheless, the overall sensory acceptability scores given by most of the school learners confirmed the satisfactory taste profile for the breakfast porridge, reinforcing the possibility of including the developed instant porridge in the NSNP breakfast programme.

5.3 Limitations of the study

The study had the following limitations:

- The study was limited to quintiles one, two and three schools; quintiles four and five schools were excluded. However, the results can be generalised to all the NSNP participating schools since the learners that participated in the study were from rural and semi-rural locations.
- The breakfast needs and preference survey and sensory assessment survey were limited to the iLembe district.
- Furthermore, children tend to be forgetful; therefore, returning consent and assent forms took longer than anticipated despite the daily reminders that the learners received from their teachers.

5.4 Strengths of the study

The current study has the following strengths that can help to enhance the impact of the study:

- The study population consisted of a diverse mixture of schools in quintiles one, two and three.
- The study ensured that the breakfast porridge being developed met the needs of school learners, thus anticipating approval.
- The objective of developing a nutritious, and cost-effective breakfast porridge benefits the health and wellness of school learners, as well as the budget of the NSNP.
- Incorporating indigenous grains and processes, such as fermentation, promotes indigenous knowledge systems, resulting in a culturally acceptable instant porridge.
- The developed instant breakfast porridge is not labour-intensive to prepare by the volunteer food handlers and requires minimum equipment during preparation.

5.5 Recommendations for further research

- Further development of this study is recommended. The study should be extended to include quintile four and five schools for the breakfast needs and preference survey and sensory assessment survey.
- Conduct further nutritional analysis to better explore the micronutrient composition.
- Use a trained sensory panel instead of a consumer sensory panel for more valid feedback throughout the product development process.
- Conduct a penalty analysis among school learners to increase the sensory acceptability of the instant porridge from four to seven. Specifically, a just-about-right (JAR) scale could be conducted among school learners to determine the strengths/weaknesses of the instant porridge and which sensory attributes should be increased or decreased during product development.
- Future studies could be conducted to assess the sensory acceptability and palatability of various cereal flavours.
- Indigenous grains or local ingredients could be utilised to develop instant porridge or similar products.
- The instant porridge could be fortified, and its impact on learner concentration, hunger reduction, and nutritional status could be conducted through a 6-month randomised control trial.
- Commercialisation of the developed porridge could contribute to the upliftment of the economy through job creation.

5.6 Recommendations for policymakers within the NSNP

- To effectively incorporate the developed instant porridge into the NSNP, it is recommended that the NSNP policymakers develop policies that incentivise local farmers to produce indigenous grains.
- Train NSNP food handlers on the preparation and storage of instant porridge.
- Launch a local campaign to raise community awareness about the health benefits of consuming sorghum and pearl millet.
- Use evaluation data to guide the modification of policies and decisions made about the products or meals that are included in the NSNP in the future.
- Partner with other non-governmental organisations (NGOs) and human nutrition specialists to gain support and knowledge regarding how best to incorporate the developed instant porridge into the NSNP Study.

5.7 Conclusion

This study identified the breakfast needs and preferences of quintile 1-3 school learners to develop a sensory acceptable, nutritious, and cost-effective breakfast porridge suitable for the NSNP to supplement the gap in the RDA shortfall that the current NSNP breakfast is failing to address. Similar studies should take into account the research's acknowledged strengths and limitations.

The researcher has included numerous recommendations for stakeholders to guide the successful incorporation of the developed porridge into the NSNP. Furthermore, the achievement of several SDGs to enhance general health and well-being is closely related to this study, which is significant. Consequently, the NSNP's incorporation of the created porridge will help achieve the objectives outlined in the aforementioned initiatives.

In essence, the study's goals have been attained. Crucial stages of the product development process were combined in this extensive study to assess the compatibility and appropriateness of the instant porridge made from sorghum and pearl millet for the NSNP. Therefore, it can be concluded that the sorghum and pearl millet-based instant porridge can enhance the NSNP to achieve its goal of improving school attendance and enhancing learners' learning capacity by providing healthy free meals.

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Appendix A: Breakfast needs assessment survey questionnaire

NSNP SURVEY QUESTIONNAIRE

Dear Learner,

The Department of Food and Nutrition at the Durban University of Technology is producing a nutritious breakfast for children in the National School Nutrition Programme (NSNP). We would appreciate it if you could take a few minutes of your time to fill in this survey. All responses are confidential and would remain anonymous.

Please answer the questions below and tick the appropriate box when applicable.

1. Please state your gender:

Boy	Girl

2. Please state your grade:

Grade 1	Grade 2	Grade 3	Grade 4	Grade 5	Grade 6
Grade 7	Grade 8	Grade 9	Grade 10	Grade 11	Grade 12

3. Please state your age:

7	8	9	10	11	12	13
14	15	16	17	18	19	20

4. Do you have breakfast before coming to school?

o Yes

o No

o Sometimes

5. If you answered "NO" or Sometimes for the above question, why do you not eat breakfast before coming to school?

o It's too early to eat

o I do not have time to eat

o There is not enough food to eat

o Other, specify_____

6. If you did not have breakfast, are you able to concentrate in class until the NSNP meal is served?
o Yes

o No

o Sometimes

7. If you eat breakfast before coming to school, at what time do you eat the breakfast?

04:00- 04:59	05:00- 05:59	06:00- 06:59	07:00- 07:59

8. What did you eat for breakfast today?
_____

9. Does your school provide a breakfast programme?
o Yes

o No

10. If you answered "Yes" to the question above, please describe the breakfast
_____

11. Which breakfast cereal do you prefer from the list below?
Instant porridge

o Jungle oats

o Weet-Bix, Kelloggs Corn Flakes, All Bran Flakes

o Future Life, ProNutro

o Other, specify_____

12. Which breakfast cereal flavour do you prefer from the list below?
o Vanilla

o Banana

o Strawberry

o Chocolate

Thank you!

Appendix B: Gatekeeper permission application letter

Application for Permission to Conduct Research in KwaZulu-Natal Department of Education Institutions

1. Applicants Details

Title: Prof / Dr / Rev / Mr / Mrs / Miss / Ms Surname: Ngcobo

Name(s) Of Applicant(s): Nqobile Email: 21801982@dut4life.ac.za

Tel No: _____ Fax: _____ Cell: 0616286417

Postal Address: 75 Greenfield Avenue, Quarry Heights, KwaMashu, Durban, 4359

2. **Proposed Research Title:** Production of a sorghum and millet-based instant breakfast cereal for the National School Nutrition Programme.

	Yes	No
3. Have you applied for permission to conduct this research or any other research within the KZNDoE institutions? If "yes", please state reference Number: _____		X
4. Is the proposed research part of a tertiary qualification? **If "yes"** **Name of tertiary institution:** Durban University of Technology **Faculty and or School:** Applied Sciences **Qualification:** Master's in Applied Sciences **Name of Supervisor:** Dr Ashika Naicker **Supervisors Signature**_____ If "no", state purpose of research: _____	X	

5. Briefly state the Research Background: South Africa's National School Nutrition Programme (NSNP) was established in 1994 as one of the government's food security intervention strategies. It was designed to address issues of hunger, and malnutrition, improve school attendance, promote a healthy lifestyle, and the right to food and education among children that come from disadvantaged backgrounds. Currently, the NSNP does not have a sustainable solution to provide learners with a nutritious breakfast. The creation of a nutritious and filling breakfast cereal for learners is essential in the fight against hunger and in ensuring that learners have the energy to maintain their focus until their next meal in light of the rising levels of food insecurity.

6. What is the main research question(s): How many learners go to school hungry? Which breakfast cereal do school learners prefer? Is the developed breakfast cereal nutritious, filling and safe? Is the developed breakfast cereal sensory acceptable?

7. Methodology including sampling procedures and the people to be included in the sample:

An average of 8 consenting students from the Department of Food and Nutrition at the Durban University of Technology who are familiar with sensory testing will be used throughout the product development trials. The study population of approximately 400 school learners aged between seven and eighteen (100 each from 4 schools) will be required for the breakfast preference survey and 200 learners (50 each from 4 schools) will be required for the consumer sensory assessments. Letters of information and Consent forms will be sent to parents. Learners that obtain their parent's consent will then provide consent if they want to participate in the study . Letters of information and Consent forms will be given to the sensory panellist for each trial. Once consent is obtained from parents, consent to take part in the study will be obtained from learners to take part in the breakfast preference and sensory survey.

8. What contribution will the proposed study make to the education, health, safety, welfare of the learners and to the education system as a whole?

The learners will benefit from the consumption of a nutritious breakfast cereal which will help keep them alert during class. Upon the successful results of this study, the recipes for the nutritious breakfast cereal will be made available to the NSNP.

KZN Department of Education Schools or Institutions from which sample will be drawn – If the list is long please attach at the end of the form		
Groutville Secondary		
Dr BW Vilakazi Primary		
Qinisani High		

Magojolo Primary		

9. Research data collection instruments: *(Note: a list and only a brief description is required here - the actual instruments must be attached)***:**

1. Breakfast needs assessment and preference survey: to investigate the need for breakfast and indicate the type of breakfast cereal school learners would prefer.
2. Sensory assessment survey: to determine the degree to which the learners like or dislike the breakfast cereal.

10. Procedure for obtaining consent of participants and where appropriate parents or guardians:

Letters of information and Consent forms will be given to the sensory panellist for each trial. The principal of each school will be contacted and permission will be granted. Letters of information and Consent forms will be sent to parents. Learners who obtain their parent's consent will then give consent if they want to participate in the study. Letters of information and Consent forms will be given to the sensory panellist for each trial. Once consent is obtained from parents, consent to take part in the study will be obtained from learners to take part in the breakfast preference and sensory survey.

11. Procedure to maintain confidentiality (if applicable): All school learners will be listed as codes in the dataset to maintain anonymity of participants. The information gathered from the survey will be kept in a storage area in the Department of Food and Nutrition at the Durban University of Technology for 5 years after which it will be destroyed. All soft datasets will be password protected and will be disposed of after 5 years.

12. Questions or issues with the potential to be intrusive, upsetting or discriminatory to participants (if applicable): Not applicable

13. Additional support available to participants in the event of disturbance resulting from intrusive questions or issues (if applicable): Not applicable

14. Research Timelines :

1. Proposal and ethics clearance: March-May 2023
2. Obtaining gatekeeper permission from the Department of Education and DUT: May-June 2023
3. Obtain permission from the chosen schools, consent from parents and consent from learners to administer a needs assessment survey: July 2023
4. Data collection: August 2023
5. Begin product development process: August-September2023
6. Conduct pilot testing (consumer sensory panel): November 2023

7. Conduct nutritional, microbial and shelf-life analysis: November-December 2023
8. Obtain permission from the chosen schools, consent from parents and consent from learners to conduct sensory analysis testing: January-February 2023
9. Conduct final sensory analysis (consumer sensory panel: learners): March 2023
10. Results, data analysis, writing of chapters: April-July 2024
11. Manuscript submission: August 2024
12. Compilation of thesis: September-October 2024
13. Submission of thesis: November 2024

15. Declaration

I hereby agree to comply with the relevant ethical conduct to ensure that participants' privacy and the confidentiality of records and other critical information.

I Nqobile Ngcobo **declare that the above information is true and correct**

13/03/2023

Signature of Applicant **Date**

16. Agreement to provide and to grant the KwaZulu-Natal Department of Education the right to publish a summary of the report.

I/We agree to provide the KwaZulu-Natal Department of Education with a copy of any report or dissertation written on the basis of information gained through the research activities described in this application.

I/We grant the KwaZulu-Natal Department of Education the right to publish an edited summary of this report or dissertation using the print or electronic media.

13/03/2023

Signature of Applicant(s) **Date**

Return a completed form to:

Sibusiso Alwar

The Research Unit; Resource Planning; KwaZulu Natal Department of Education

Hand Delivered:

Office G25; 188 Pietermaritz Street; Pietermaritzburg; 3201

Or

Ordinary Mail

Private Bag X9137; Pietermaritzburg; 3200

Or

Email

sibusiso.alwar@kzndoe.gov.za

Appendix C: **Gatekeeper permission award letter**

KWAZULU-NATAL PROVINCE
EDUCATION
REPUBLIC OF SOUTH AFRICA

OFFICE OF THE HEAD OF DEPARTMENT

Private Bag X9137, PIETERMARITZBURG, 3200
Anton Lembede Building, 247 Burger Street, Pietermaritzburg, 3201
Tel: 033 392 1051
Email: Phindile.duma@kzndoe.gov.za

Enquiries: Mrs B.T. Ntuli **Ref.**:2/4/8/7485

Miss Nqobile Ngcobo
75 Greenfield Avenue
Quarry Heights
KwaMashu
DURBAN
4359

Dear Miss Ngcobo

PERMISSION TO CONDUCT RESEARCH IN THE KZN DoE INSTITUTIONS

Your application to conduct research entitled: "**PRODUCT DEVELOPMENT OF A SORGHUM AND MILLET BASED INSTANT BREAKFAST CEREAL SUITABLE FOR THE NATIONAL SCHOOL NUTRITION PROGRAMME:.**", in the KwaZulu-Natal Department of Education institutions has been approved. The conditions of the approval are as follows:

1. The researcher will make all the arrangements concerning the research and interviews.
2. The researcher must ensure that Educator and learning programmes are not interrupted.
3. Interviews are not conducted during the time of writing examinations in schools.
4. Learners, Educators, Schools and Institutions are not identifiable in any way from the results of the research.
5. A copy of this letter is submitted to District Managers, Principals and Heads of Institutions where the Intended research and interviews are to be conducted.
6. The period of investigation is limited to the period from **6TH June 2023 to 31st December 2025**.
7. Your research and interviews will be limited to the schools you have proposed and approved by the Head of Department. Please note that Principals, Educators, Departmental Officials and Learners are under no obligation to participate or assist you in your investigation.
8. Should you wish to extend the period of your survey at the school(s), please contact Mrs Buyi Ntuli at the contact numbers above.
9. Upon completion of the research, a brief summary of the findings, recommendations or a full report/dissertation/thesis must be submitted to the research office of the Department. Please address it to The Office of the HOD, Private Bag X9137, Pietermaritzburg, 3200.
10. Please note that your research and interviews will be limited to schools and institutions in KwaZulu-Natal Department of Education.

Mr GN Ngcobo
Head of Department: Education
Date: 06TH June 2023

Appendix D: Letter of information for breakfast needs assessment survey participants

LETTER OF INFORMATION: SURVEY PARTICIPANTS

Title of the Research Study: Production of a sorghum and millet-based instant breakfast cereal for the National School Nutrition Programme

Principal Investigator/s/researcher: Nqobile Ngcobo

Co-Investigator/s/supervisor/s: Dr. Ashika Naicker, and Dr Nokuthula Vilakazi,

Dear Learner,

I hope that you are having a great day. I am a researcher from the Durban University of Technology (DUT). I would like to invite you to participate in the research study, titled "Production of a sorghum and millet-based instant breakfast cereal for the National School Nutrition Programme". The purpose of this cross-sectional and exploratory research is to formulate a ready to eat convenient breakfast cereal made with sorghum and millet to ensure that hunger is not a barrier to learning. The research will be conducted within the iLembe district in KwaZulu- Natal. By participating in the study, you will be one of 400 learners from four schools that receive meals from the NSNP: Magojolo Primary, Dr BW Vilakazi Primary, Qinisani High, and Groutville Secondary School. The nature of the study will be based on product development and sensory acceptability. The researcher will conduct a survey to determine the need and preference for breakfast amongst the selected schools in order to decide on a suitable breakfast cereal to be developed. The developed breakfast cereal will then go through a sensory analysis using a consumer panel, thereafter the product will go through a nutritional analysis to determine the nutritional properties of the breakfast cereal, as well as microbiological testing to deem the product safe for consumption. The product will then undergo shelf life testing and lastly be presented to you for final sensory analysis and to determine sensory acceptability of the developed breakfast cereal using a simple 7-point facial Hedonic survey. The results of each stage of the methodology will determine if the breakfast cereal developed is suitable for incorporation into the NSNP as a way of improving the program's effectiveness and will ensure that hunger is not a barrier to learning by providing a healthy and nutritious breakfast which will result in significant heath and nutritional benefits to school learners.

Outline of the Procedures:

This study uses non-invasive methods. A questionnaire survey will be conducted. The study will be explained in detail to you before the questionnaire survey is administered. You must sign a consent form agreeing to take part in the study on a voluntarily basis. The questionnaire survey is administered during school hours. The survey contains questions that investigate your breakfast preferences. The survey should not take up more than 5 minutes.

Risks or Discomforts to the Participant:

There are no potential risks to you if you participate in this study.

Explain to the participant the reasons he/she may be withdraw from the Study:

Participation will be voluntary, and you will be allowed to withdraw at any time from the study.

Benefits:

You will benefit from the consumption of a nutritious breakfast cereal which will help keep you alert during class. Upon receiving the successful results of this study, the recipes for the nutritious breakfast cereal will be made

available to the NSNP. The researcher will benefit by obtaining the necessary data required to complete a Master's degree in Food and Nutrition.

Remuneration:
You will not receive any remuneration for participation in this study.

Costs of the Study:
No costs will be expected to be covered by you if you choose to volunteer your participation in this research study.

Confidentiality:
The information gathered will be of a confidential nature and will not seek to jeopardize the school's status nor your identity or status if you choose to be involved in the study. Data will be saved in confidence. No form of identity will be required from you which will further ensure confidentiality of the data. The data collected will be stored in the Department of Food and Nutrition in a lockable cupboard for 5 years after which it will be disposed of by shredding and electronic data will be securely stored and deleted after 5 years.

Results:
The academic property rights will belong to the DUT. Publication of the study will be made available to those that request it.

Research-related Injury:
This study poses no threats to your health nor will it inflict any type of mental or physical injury should you choose to participate.

Storage of all electronic and hard copies including tape recordings:
Data will be stored in the Durban University of Technology server. This information will only be available to the research team for a retention period of 5years.

Persons to contact in the Event of any Problems or Queries: Please contact the researcher: Nqobile Ngcobo (0616286417 or 21801982@dut4life.ac.za) or the supervisor: Dr. Ashika Naicker (0313732335 or 0822009726 or ashikan@dut.ac.za) or the DUT-Institutional Research Ethics Administrator on 031 373 2375. Complaints can be reported to the Acting Director: Research and Postgraduate Support on researchdirector@dut.ac.za.

Appendix E: Letter of information for parents/guardians

LETTER OF INFORMATION: PARENTS/GUARDIANS

Title of the Research Study: Production of a sorghum and millet-based instant breakfast cereal for the National School Nutrition Programme

Principal Investigator/s/researcher: Nqobile Ngcobo

Co-Investigator/s/supervisor/s: Dr. Ashika Naicker, and Dr. Nokuthula Vilakazi,

Dear Parent/Guardian,

I hope that this letter finds you in good health. I am a researcher from the Durban University of Technology (DUT). I would like to invite you to participate in the research study, titled "Production of a sorghum and millet-based instant breakfast cereal for the National School Nutrition Programme". The purpose of this cross-sectional and exploratory research is to formulate a ready to eat convenient breakfast cereal made with sorghum and millet to ensure that hunger is not a barrier to learning. The research will be conducted within the iLembe district in KwaZulu-Natal. Your child will comprise one of 400 learners from four schools that receive meals from the NSNP: Magojolo Primary, Dr BW Vilakazi Primary, Qinisani High, and Groutville Secondary schools. The nature of the study will be based on product development and sensory acceptability. The researcher will conduct a survey to determine the need and preference for breakfast among the learners at the selected schools in order to decide on a suitable breakfast cereal to be developed. The developed breakfast cereal will then go through a sensory analysis using a consumer panel, thereafter the product will go through a nutritional analysis to determine the nutritional properties of the breakfast cereal, as well as microbiological testing to deem the product safe for consumption. The product will then undergo shelf life testing and lastly will be presented to your child for final sensory analysis and to determine sensory acceptability of the developed breakfast cereal using a simple 7-point facial Hedonic survey. The results of each stage of the methodology will determine if the breakfast cereal developed is suitable for incorporation into the NSNP as a way of improving the program's effectiveness and to ensure that hunger is not a barrier to learning by providing a healthy and nutritious breakfast which will result in significant heath and nutritional benefits to school learners.

Outline of the Procedures:

The aim of this study is to investigate, determine and develop a suitable breakfast cereal for learners in public primary schools to supplement the National School Nutrition Program (NSNP) in providing primary school learners with nutritious food and to ensure that children start their learning day with high energy and concentration levels. Prior to the development of the breakfast cereal, a breakfast preference survey will be presented to your child. After data has been collected, a suitable breakfast will be developed for your child. During the school day, consenting learners that are part of the NSNP will be presented with a breakfast which they will be required to taste and then complete a sensory assessment form. This will take 10 minutes of school time.

Risks or Discomforts to the Participant:

There are no potential risks to your child unless the participant suffers from any allergic reaction from potential allergens which will be declared before the sensory analysis to parents and to the child.

Explain to the participant the reasons he/she may be withdraw from the Study:

Participation will be voluntary, and your child will be allowed to withdraw at any time from the study.

Benefits:
Your child will benefit from the consumption of a nutritious breakfast cereal which will help keep them alert during class. Upon the successful results of this study, the recipes for the nutritious breakfast cereal will be made available to the NSNP. The researcher will benefit by obtaining the necessary data required to complete a Master's degree in Food and Nutrition.

Remuneration:
Your child will not receive any remuneration for participation on this study.

Costs of the Study:
No costs will be expected to be covered by your child if they choose to volunteer their participation in this research study.

Confidentiality:
The information gathered will be of a confidential nature and will not seek to jeopardise the school's status nor the identity or status of your child who chooses to be involved in the study. Data will be saved confidentially. No form of identity will be required from your child which will further ensure confidentiality of the data. The data collected will be stored in the Department of Food and Nutrition in a lockable cupboard for 5 years after which it will be disposed of by shredding and electronic data will be securely stored and deleted after 5 years.

Results:
The academic property rights will belong to the DUT. Publication of the study will be made available to those that request it.

Research-related injury:
This study poses no threats to your child's health nor will it inflict any type of mental or physical injury should they choose to participate.

Storage of all electronic and hard copies including tape recordings:
Data will be stored in the Durban University of Technology server. This information will only be available to the research team for a retention period of 5years.

Persons to contact in the Event of Any Problems or Queries: Please contact the researcher: Nqobile Ngcobo (0616286417 or 21801982@dut4life.ac.za) or the supervisor: Dr. Ashika Naicker (0313732335 or 0822009726 or ashikan@dut.ac.za) or the DUT-Institutional Research Ethics Administrator on 031 373 2375. Complaints can be reported to the Acting Director: Research and Postgraduate Support on researchdirector@dut.ac.za

Appendix F: Consent form for parents

CONSENT FORM

Full Title of the Study: Production of a sorghum and millet-based instant breakfast cereal for the National School Nutrition Programme

Names of Researcher/s: Miss Nqobile Ngcobo

Statement of Agreement for your child to Participate in the Research Study:

□ I hereby confirm that I have been informed by the researcher, Nqobile Ngcobo about the nature, conduct, benefits and risks of this study and my child's involvement in this study - Research Ethics Clearance Number: 103/23

□ I have also received, read and understood the above written information (Participant Letter of Information) regarding the study.

□The above written information (Participant Letter of Information) was read to me when necessary.

□ I am aware that the results of the study, including personal details regarding the sex, age, date of birth, initials and diagnosis of my child will be anonymously processed into a study report.

□ In view of the requirements of the research, I agree that the data collected from my child during this study can be processed in a computerized system by the researcher.

□ I understand that my child may, at any stage, without prejudice, withdraw consent to and participation in the study.

□ I have had sufficient opportunity to ask questions and (of my own free will) declare that my child is prepared to participate in the study.

□ I understand that significant new findings developed during the course of this research which mayrelate to my child's participation will be made available to me.

Full Name of Parent	**Date**	**Time**	**Signature**

I, Nqobile Ngcobo herewith confirm that the above parent has been fully informed about the nature, conduct and risks of the above study, and is willing to allow their child to participate in this research study.

Full Name of Researcher	**Date**	**Signature**
Full Name of Witness (If applicable)	**Date**	**Signature**

Appendix G: Assent form for breakfast need and preference survey questionnaire

ASSENT FORM FOR MINORS

TITLE OF THE RESEARCH PROJECT: Production of a sorghum and millet-based instant breakfast cereal for the National School Nutrition Programme

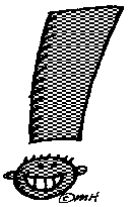
RESEARCHERS' NAME(S): Nqobile Ngcobo, Dr. Ashika Naicker, Dr. Nokuthula Vilakazi

RESEARCHERS' CONTACT NUMBER: Nqobile Ngcobo (0616286417) or Dr. Ashika Naicker (0313732335 or 0822009726)

What is a research study?

Research studies help us learn new things. We can test new ideas. First, we ask a question. Then we try to find the answer. This paper talks about our research and the choice that you have to take part in it. We want you to ask us any questions that you have. You can ask questions at any time.

Important things to know…



You get to decide if you want to take part.
You can say 'No' or you can say 'Yes'.
No one will be upset if you say 'No'.
If you say 'Yes', you can always say 'No' later.
You can say 'No' at any time.
We would still take good care of you no matter what you decide.

Why are we doing this research?

We are doing this research to find out more about the need for breakfast at your school and the breakfast that you prefer so we can make a breakfast cereal that is suitable for your needs.

Why have I been invited to take part in this research project?

You are invited to take part in this research because you are a learner at a school that receives the government school feeding scheme.

Who is doing the research?

Nqobile Ngcobo, a Master's degree student at the Durban University of Technology is doing the project to improve the challenges faced by the school feeding scheme. Currently the school feeding scheme does not offer breakfast. This study aims to develop a breakfast for the school feeding scheme.

What will happen to me in this study?

If you decide to be in the research, we would ask you to do the following:
Talking: A person on the research team would ask you questions. Then you would say your answers aloud. We will ask you questions to find out whether you have breakfast at home and what type of breakfast you would like to have at school.

Can anything bad happen to me?
Nothing bad will happen to you should you choose to participate.

Can anything good happen to me?
You will benefit from eating a healthy breakfast cereal which will help keep you alert during class.

What else should I know about this research?
If you do not want to be in the study, you do not have to be.
It is also OK to say 'yes' and change your mind later. You can stop at any time. If you want to stop, please tell the researcher. You can say 'no' to what we ask you to do for the research at any time and we will stop.

Will anyone know I am in the study?
Your participation in the study will be kept confidential, but information about you will be given to the study supervisor.

Who can I talk to about the study?
Researcher: Nqobile Ngcobo (0616286417) or the supervisor: Dr. Ashika Naicker (0313732335 or 0822009726)

What if I do not want to do this?
You can refuse to take part even if your parents have agreed to your participation. You can stop being in the study at any time without getting into trouble.

Do you have any other questions?
If you want to be in the research after we talk, please write your name below. We will write our name too. This shows we talked about the research and that you want to take part.

Do you understand this research study and are you willing to take part in it?

YES	NO

Has the researcher answered all your questions?

YES	NO

Do you understand that you can STOP being in the study at any time?

YES	NO

Name of Participant _____
(To be written by child/adolescent)

Printed Name of Researcher: Nqobile Ngcobo

Signature of Researcher _

03/03/2023
Date

11:30
Time

Appendix H: Cleaning checklist

Sorghum and pearl millet based instant porridge cleaning checklist

Date: _____

Use the checklist below to ensure cleaning is done before each production session

Process step	Cleaning task	Yes	No
Sourcing of ingredients	Clean and disinfect surfaces in the area where ingredients are inspected upon delivery.		
Fermentation	Clean and sanitize all the equipment.		
	Autoclave all ingredients and flasks.		
	Clean pH meter after each use		
Cooking	Thoroughly clean and sanitize equipment used for cooking, including pots, pans, and cooking utensils.		
	Wipe down surfaces adjacent to cooking equipment to avoid cross-contamination.		
	Sanitize food thermometers before and after each use.		
Drying	Clean and sanitize the interior of drying equipment.		
	Clean and sanitize drying trays prior to use.		
	Sanitize any surfaces where the dried porridge is handled		
Packaging	Clean and sanitize all surfaces in the packaging area prior to packaging the porridge.		
	Ensure that storage boxes for packaging materials are regularly cleaned.		
	Sanitize stations where packaging is inspected.		
Storage	Regularly clean floors and walls in storage area.		
	Sanitize surfaces where ingredients and the instant porridge baths are stored regularly.		
	Check for signs of infestation and clean the area if any are found, using appropriate pest control methods.		
Packaging	Sanitize surfaces and equipment used for handling the instant porridge before packaging.		
	Package porridge sample in sterile containers to conduct nutritional, microbial and shelf-life tests.		
Microbiological and shelf-life test	Ensure that all testing instruments and surfaces are cleaned and sterilized before and after use.		

Appendix I: Sensory Analysis Assessment Form for consumer sensory panel

SENSORY ANALYSIS ASSESSMENT FORM

AGE: _____

GENDER: (tick the appropriate box)

Male	Female

INSTRUCTIONS:
Please take a sip of water before starting.
Please taste the breakfast cereal, tick how much you like or dislike the breakfast cereal and provide a comment.

	Appearance/Colour	Taste/Flavour	Texture/mouthfeel	Smell/Aroma
Like extremely				
Like very much				
Like moderately				
Like slightly				
Neither like or dislike				
Dislike slightly				
Dislike moderately				
Dislike very much				
Dislike extremely				

Comments:

Appendix J: Letter of information for consumer sensory assessment panel

LETTER OF INFORMATION

Title of the Research Study: Production of a sorghum and millet-based instant breakfast cereal for the National School Nutrition Programme

Principal Investigator/s/researcher: Nqobile Ngcobo

Co-Investigator/s/supervisor/s: Dr. Ashika Naicker, and Dr Nokuthula Vilakazi

Dear student,

I hope that you are having a great day. I am a researcher from the Durban University of Technology (DUT). I would like to invite you to participate in the research study, titled "Production of a sorghum and millet-based instant breakfast cereal for the National School Nutrition Programme". The purpose of this cross-sectional and exploratory research is to formulate a ready to eat convenient breakfast cereal made with sorghum and millet to ensure that hunger is not a barrier to learning. The research will be conducted within the iLembe district in KwaZulu- Natal. A sample population of 400 learners from four schools that receive meals from the NSNP: Magojolo Primary, Dr BW Vilakazi Primary, Qinisani High, and Groutville Secondary School. The nature of the study will be based on product development and the sensory acceptability. The researcher will conduct a survey to determine the need and preference for breakfast amongst the selected schools in order to decide on a suitable breakfast cereal to be developed. The developed breakfast cereal will then go through a sensory analysis using a consumer panel, thereafter the product will go through a nutritional analysis to determine the nutritional properties of the breakfast cereal, as well as microbiological testing to deem the product safe for consumption. The product will then undergo shelf life testing and lastly will be presented to school learners for final sensory analysis and to determine sensory acceptability of the developed breakfast cereal using a simple 7-point facial Hedonic survey. The results of each stage of the methodology will determine if the breakfast cereal developed is suitable for incorporation into the NSNP as a way of improving the program's effectiveness and to ensure that hunger is not a barrier to learning by providing a healthy and nutritious breakfast which will result in significant heath and nutritional benefits to school learners.

Outline of the Procedures:

This study uses non-invasive methods. You have been invited because you have had prior training and have the required sensory tasting skills that are important for this study. The study will be explained to you in detail before sensory analysis takes place. You will need to sign a consent form agreeing to take part in the study on a voluntary basis. The breakfast cereal will be presented to you to evaluate at the Department of Food and Nutrition Research laboratory. This will take you no more than 10 minutes to evaluate. Once you are done, you will receive a fruit as a gesture of gratitude.

Risks or Discomforts to the Participant:

There are no potential risks to you unless you suffer from any allergic reaction from potential allergens which will be declared before the sensory analysis.

Explain to the participant the reasons he/she may be withdraw from the study:

Participation will be voluntary, and you will be allowed to withdraw at any time from the study.

Benefits:
Learners in schools that are part of the NSNP will benefit from the consumption of a nutritious breakfast cereal which will help keep them alert during class. Upon receiving the successful results of this study, the recipes for the nutritious breakfast cereal will be made available to the NSNP. The researcher will benefit by obtaining the necessary data required to complete a Master's degree in Food and Nutrition.

Remuneration:
You will not receive any remuneration for participation on this study.

Costs of the Study:
No costs will be expected to be covered by your child if they choose to volunteer their participation in this research study.

Confidentiality:
The information gathered will be of a confidential nature and will not seek to jeopardize the school's status nor the identity or status of your child who chooses to be involved in the study. Data will be saved in confidence. No form of identity will be required from your child which will further ensure confidentiality of the data. The data collected will be stored in the Department of Food and Nutrition in a lockable cupboard for 5 years after which it will be disposed of by shredding and electronic data will be securely deleted after 5 years.

Results:
The academic property rights will belong to the DUT. Publication of the study will be made available to those that request it.

Research-related Injury:
This study poses no threats to your health nor does it inflict any in type of mental or physical injury should you choose to participate.

Storage of all electronic and hard copies including tape recordings:
Data will be stored in the Durban University of Technology server. This information will only be available to the research team for a retention period of 5years.

Persons to contact in the Event of Any Problems or Queries: Please contact the researcher: Nqobile Ngcobo (0616286417 or 21801982@dut4life.ac.za) or the supervisor: Dr. Ashika Naicker (0313732335 or 0822009726 or ashikan@dut.ac.za) or the DUT-Institutional Research Ethics Administrator on 031 373 2375. Complaints can be reported to the Acting Director: Research and Postgraduate Support on researchdirector@dut.ac.za.

Appendix K: Consent form for consumer sensory panel

CONSENT FORM

Full Title of the Study: Production of a sorghum and millet-based instant breakfast cereal for the National School Nutrition Programme

Names of Researcher/s: Miss Nqobile Ngcobo

Statement of Agreement for Participating in the Research Study:

□ I hereby confirm that I have been informed by the researcher, Nqobile Ngcobo about the nature, conduct, benefits and risks of this study and my involvement in this study - Research Ethics Clearance Number: 103/23

□ I have also received, read and understood the above written information (Participant Letter of Information) regarding the study.

□ I am aware that the results of the study, including my personal details regarding the sex, age, date of birth, initials and diagnosis will be anonymously processed into a study report.

□ In view of the requirements of research, I agree that the data collected from me during this study can be processed in a computerized system by the researcher.

□ I understand that I may, at any stage, without prejudice, withdraw consent and participation in the study.

□ I have had sufficient opportunity to ask questions and (of my own free will) declare myself prepared to participate in the study.

□ I understand that significant new findings developed during the course of this research which may relate to my participation will be made available to me.

Full Name of Participant	**Date**	**Signature**

I, Nqobile Ngcobo herewith confirm that the above parent has been fully informed about the nature, conduct and risks of the above study, and is willing to allow their child to participate in this research study.

Full Name of Researcher	**Date**	**Signature**

_____	_____	_____
Full Name of Witness (If applicable)	**Date**	**Signature**

_____	_____	_____
Full Name of Legal Guardian (If applicable)	**Date**	**Signature**

Appendix L: Letter of information for sensory assessment for learners

LETTER OF INFORMATION

Title of the Research Study: Production of a sorghum and millet-based instant breakfast cereal for the National School Nutrition Programme

Principal Investigator/s/researcher: Nqobile Ngcobo

Co-Investigator/s/supervisor/s: Dr. Ashika Naicker and Dr Nokuthula Vilakazi

Dear Learner

I hope that you are having a great day. I am a researcher from the Durban University of Technology (DUT). I would like to invite you to participate in the research study, titled "Production of a sorghum and millet-based instant breakfast cereal for the National School Nutrition Programme". The purpose of this cross-sectional and exploratory research is to formulate a ready to eat convenient breakfast cereal made with sorghum and millet to ensure that hunger is not a barrier to learning. The research will be conducted within the iLembe district in KwaZulu- Natal. By participating in the study, you will comprise one of 400 learners from four schools that receive meals from the NSNP: Magojolo Primary, Dr BW Vilakazi Primary, Qinisani High, and Groutville Secondary schools. The nature of the study will be based on product development and sensory acceptability. The researcher will conduct a survey to determine the need and preference for breakfast [cereal] amongst the selected schools in order to decide on a suitable breakfast cereal to be developed. The developed breakfast cereal will then go through a sensory analysis using a consumer panel, thereafter the product will go through a nutritional analysis to determine the nutritional properties of the breakfast cereal, as well as microbiological testing to deem the product safe for consumption. The product will then undergo shelf life testing and lastly be presented to you for final sensory analysis and to determine sensory acceptability of the developed breakfast cereal using a simple 7-point facial Hedonic survey. The results of each stage of the methodology will determine if the breakfast cereal developed is suitable for incorporation into the NSNP as a way of improving the program's effectiveness and to ensure that hunger is not a barrier to learning by providing a healthy and nutritious breakfast which will result in significant heath and nutritional benefits to school learners.

Outline of the procedure:

This study uses non-invasive methods. Sensory analysis will be conducted. The study will be explained to you in detail before sensory analysis takes place. You will need to sign a consent form agreeing to take part in the study on a voluntarily basis. During the school day, the breakfast cereal will be presented to you to evaluate. This will take you no more than 5 minutes to evaluate. Once you are done, you will receive a fruit as a gesture of gratitude.

Risks or discomforts to the participant:

There are no potential risks to you unless you suffer from any allergic reaction from potential allergens which will be declared before the sensory analysis to you.

Explain to the participant the reasons he/she may withdraw from the study:

Participation will be voluntary, and you will be allowed to withdraw at any time from the study.

Benefits:
You will benefit from the consumption of a nutritious breakfast cereal which will help keep you alert during class. Upon the successful results of this study, the recipes for the nutritious breakfast cereal will be made available to the NSNP. The researcher will benefit by obtaining the necessary data required to complete a Master's degree in Food and Nutrition.

Remuneration:
You will not receive any remuneration for participation on this study.

Costs of the Study:
No costs will be expected to be covered by you if you choose to volunteer your participation in this research study.

Confidentiality:
The information gathered will be of a confidential nature and will not seek to jeopardize the school's status nor your identity or status if you choose to be involved in the study. Data will be saved in confidence. No form of identity will be required from you which will further ensure confidentiality of the data. The data collected will be stored in the Department of Food and Nutrition in a lockable cupboard for 5 years after which it will be disposed for shredding and electronic data will be securely deleted after 5 years.

Results:
The academic property rights will belong to the DUT. Publication of the study will be made available to those that request it.

Research-related injury:
This study poses no threats to your health nor does it inflict any type of mental or physical injury should you choose to participate.

Storage of all electronic and hard copies including tape recordings:
Data will be stored on the Durban University of Technology server. This information will only be available to the research team for a retention period of 5 years.

Persons to contact in the event of any problems or queries: Please contact the researcher: Nqobile Ngcobo (0616286417 or 21801982@dut4life.ac.za) or the supervisor: Dr. Ashika Naicker (0313732335 or 0822009726 or ashikan@dut.ac.za) or the DUT-Institutional Research Ethics Administrator on 031 373 2375. Complaints can be reported to the Acting Director: Research and Postgraduate Support on researchdirector@dut.ac.za.

Appendix M: Letter of information for parents/guardians

LETTER OF INFORMATION: PARENTS/GUARDIANS

Title of the Research Study: Title of the Research Study: Production of a sorghum and millet-based instant breakfast cereal for the National School Nutrition Programme

Principal Investigator/s/researcher: Nqobile Ngcobo

Co-Investigator/s/supervisor/s: Dr. Ashika Naicker, and Dr. Nokuthula Vilakazi,

Dear Parent/Guardian,
I hope that this letter finds you in good health. I am a researcher from the Durban University of Technology (DUT). I would like to invite you to participate in the research study, titled "Production of a sorghum and millet-based instant breakfast cereal for the National School Nutrition Programme". The purpose of this cross-sectional and exploratory research is to formulate a ready to eat convenient breakfast cereal made with sorghum and millet to ensure that hunger is not a barrier to learning. The research will be conducted within the iLembe district in KwaZulu-Natal. Your child will comprise of 400 learners from four schools that receive meals from the NSNP: Magojolo Primary, Dr BW Vilakazi Primary, Qinisani High, and Groutville Secondary School. The nature of the study will be based on product development and the sensory acceptability. The researcher will conduct a survey to determine the need and preference for breakfast among the selected schools in order to decide on a suitable breakfast cereal to be developed. The developed breakfast cereal will then go through a sensory analysis using consumer panel, thereafter the product will go through a nutritional analysis to determine the nutritional properties of the breakfast cereal, as well as microbiological testing to deem the product safe for consumption. The product will then undergo shelf life testing and lastly be presented to your child for final sensory analysis and to determine sensory acceptability of the developed breakfast cereal using a simple 7-point facial Hedonic survey. The results of each stage of the methodology will determine if the breakfast cereal developed is suitable for incorporation into the NSNP as a way of improving the program's effectiveness and to ensure that hunger is not a barrier to learning by providing a healthy and nutritious breakfast which will result in significant heath and nutritional benefits to school learners.

Outline of the Procedures:
The aim of this study is to investigate, determine and develop a suitable breakfast cereal for learners in public primary schools to supplement the National School Nutrition Program (NSNP) in providing primary school learners with nutritious food and to ensure that children start their learning day with high energy and concentration levels. Prior to the development of the breakfast cereal, a breakfast preference survey will be presented to your child. After data has been collected, a suitable breakfast would be developed for your child. During the school day, consenting learners that are part of the NSNP will be presented with a

breakfast which they will be required to taste and complete a sensory assessment form. This will take 10 minutes of school time.

Risks or Discomforts to the Participant:
There are no potential risks to your child unless the participant suffers from any allergic reaction from potential allergens which will be declared before the sensory analysis to parents and to the child.

Explain to the participant the reasons he/she may be withdraw from the Study:
Participation will be voluntarily, and your child will be allowed to withdraw at any time of the study.

Benefits:
Your child will benefit from the consumption of a nutritious breakfast cereal which will help keep them alert during class. Upon the successful results of this study, the recipes for the nutritious breakfast cereal will be made available to the NSNP. The researcher will benefit by obtaining the necessary data required to complete a Master's degree in Food and Nutrition.

Remuneration:
Your child will not receive any remuneration for participation on this study.

Costs of the Study:
No costs will be expected to be covered by your child if they choose to volunteer their participation in this research study.

Confidentiality:
The information gathered will be of a confidential nature and will not seek to jeopardise the school's status nor the identity or status of your child who chooses to be involved in the study. Data will be saved in confidence. No form of identity will be required from your child which will further ensure confidentiality of the data. The data collected will be stored in the Department of Food and Nutrition in a lockable cupboard for 5 years after which it will be disposed for shredding and electronic data will be securely deleted after 5 years.

Results:
The academic property rights will belong to the DUT. Publication of the study will be made available to those that request it.

Research-related Injury:
This study poses no threats to your child's health nor does it inflict any in type of mental or physical injury should you choose to participate.

Storage of all electronic and hard copies including tape recordings:
Data will be stored in the Durban University of Technology server. This information will only be available to the research team for a retention period of 5years.

Persons to contact in the Event of Any Problems or Queries: Please contact the researcher: Nqobile Ngcobo (0616286417 or 21801982@dut4life.ac.za) or the supervisor: Dr. Ashika Naicker (0313732335 or 0822009726 or ashikan@dut.ac.za) or the DUT-Institutional Research Ethics Administrator on 031 373 2375. Complaints can be reported to the Acting Director: Research and Postgraduate Support on researchdirector@dut.ac.za.

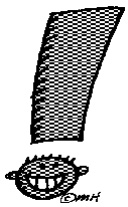
Appendix N: Assent form for sensory assessment

ASSENT FORM FOR MINORS

TITLE OF THE RESEARCH PROJECT: Production of a sorghum and millet-based instant breakfast cereal for the National School Nutrition Programme
RESEARCHERS' NAME(S): Nqobile Ngcobo, Dr. Ashika Naicker, Dr. Nokuthula Vilakazi
RESEARCHERS' CONTACT NUMBER: Nqobile Ngcobo (0616286417) or Dr. Ashika Naicker (0313732335 or 0822009726)

What is a research study?
Research studies help us learn new things. We can test new ideas. First, we ask a question. Then we try to find the answer.
This paper talks about our research and the choice that you have to take part in it. We want you to ask us any questions that you have. You can ask questions any time.

Important things to know…
You get to decide if you want to take part.
You can say 'No' or you can say 'Yes'.
No one will be upset if you say 'No'.
If you say 'Yes', you can always say 'No' later.
You can say 'No' at any time.
We would still take good care of you no matter what you decide.



Why are we doing this research?
We are doing this research to find out how much you like or dislike the breakfast cereal that we have made for the school feeding scheme**.**

Why have I been invited to take part in this research project?
You are invited to take part in this research because you are a learner at a school that receives the government school feeding scheme.

Who is doing the research?

Nqobile Ngcobo, a master's student at the Durban University of Technology is doing the project to improve the challenges faced by the school feeding scheme. Currently the school feeding scheme does not offer breakfast. This study aims to develop a breakfast for the school feeding scheme.

What will happen to me in this study?
If you decide to be in the research, we would ask you to do the following:
Taste and evaluate the breakfast cereal: A person on the research team will present the assessment form and breakfast cereal to you at school. You will taste the breakfast cereal and tick how much you like or dislike the breakfast cereal on the form.

Can anything bad happen to me?
Nothing bad will happen to you should you choose to participate.

Can anything good happen to me?
You will benefit from eating a healthy breakfast cereal which will help keep you alert during class.

What else should I know about this research?
If you do not want to be in the study, you do not have to be.
It is also OK to say yes and change your mind later. You can stop at any time. If you want to stop, please tell the researcher. You can say 'no' to what we ask you to do for the research at any time and we will stop.

Will anyone know I am in the study?
Your participation in the study will be kept confidential, but information about you will be given to the study supervisor.

Who can I talk to about the study?
Researcher: Nqobile Ngcobo (0616286417) or the supervisor: Dr. Ashika Naicker (0313732335 or 0822009726)

What if I do not want to do this?
You can refuse to take part even if your parents have agreed to your participation. You can stop being in the study at any time without getting in trouble.

Do you have any other questions?
If you want to be in the research after we talk, please write your name below. We will write our name too. This shows we talked about the research and that you want to take part.

Do you understand this research study and are you willing to take part in it?

YES	NO

Has the researcher answered all your questions?

YES	NO

Do you understand that you can STOP being in the study at any time?

YES	NO

Name of Participant _____
(To be written by child/adolescent)

Printed Name of Researcher: Nqobile Ngcobo

Signature of Researcher

03/03/2023 **Date** 11:30 **Time**

Appendix O: Sensory Analysis Assessment Form for Learners

SENSORY ANALYSIS ASSESSMENT FORM

Please answer the questions below and tick the appropriate box when applicable.

AGE: _____

GENDER:

Boy	Girl

GRADE:

Grade 1	Grade 2	Grade 3	Grade 4	Grade 5	Grade 6
Grade 7	Grade 8	Grade 9	Grade 10	Grade 11	Grade 12

INSTRUCTIONS:

Please take a sip of water before starting.

Please taste the breakfast cereal and tick the face that best describes how much you like or dislike the breakfast cereal.

						
Super bad	Really bad	Bad	Maybe good or maybe bad	Good	Really good	Super good

Appendix P: Research ethical clearance award letter

Institutional Research Ethics Committee
Research and Postgraduate Support Directorate
2nd Floor, Berwyn Court
Gate 1, Steve Biko Campus
Durban University of Technology

P O Box 1334, Durban, South Africa, 4001

Tel: 031 373 2375
Email: lavishad@dut.ac.za
http://www.dut.ac.za/research/institutional_research_ethics

www.dut.ac.za

22 June 2023

Ms N Ngcobo
2624 Greenfield Avenue
Quarry Heights
Durban
4359

Dear Ms Ngcobo

Production of a sorghum and millet-based instant breakfast cereal for the National School Nutrition Programme
Ethics Clearance Number: IREC 103/23

The DUT-Institutional Research Ethics Committee acknowledges receipt of your final data collection tool for review.

We are pleased to inform you that the data collection tool has been approved. Kindly ensure that participants used for the pilot study are not part of the main study.

In addition, the DUT-IREC acknowledges receipt of your gatekeeper permission letter.

Please note that FULL APPROVAL is granted to your research proposal. You may proceed with data collection.

Any adverse events [serious or minor] which occur in connection with this study and/or which may alter its ethical consideration must be reported to the DUT-IREC according to the DUT-IREC SOP's.

Please note that any deviations from the approved proposal require the approval of the DUT-IREC as outlined in the DUT-IREC SOP's.

It is compulsory for a student or researcher to apply for recertification on an annual basis. The failure to do so will result in withdrawal of ethics clearance. It is the responsibility of the researcher and the supervisor to apply for recertification.

Please note that you are required to submit a Notification of Completion of Study form together with an abstract to the DUT-IREC office on completion of your study.

Yours Sincerely

Prof J K Adam
Chairperson: DUT-IREC