NUTRITIONAL VALUE OF TRADITIONAL LEAFY VEGETABLES IN KWA-ZULU NATAL

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PREFACE

This study represents original work by the author and has not been submitted in any form to another university or institute. Where use was made of the work of others, it has been duly acknowledged in the text.

The research described in this thesis was carried out at the Department of Biotechnology, Durban Institute of Technology, M. L. Sultan Campus, under the supervision of Professor B. Odhav.

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ABBREVIATIONS

(AOAC) Association of Official Analytical Chemists

(AA) Atomic absorption

(β-carotene) Beta-carotene

(Ca) Calcium

(Cu) Copper

(HCl) Hydrochloric acid

(ICP) Inductively coupled plasma

(Fe) Iron

(kcal) Kilocalorie

(kJ) Kilojoules

(Mg) Magnesium

(Mn) Manganese

(MES) N-Morpholino-ethanosulphonic

(P) Phosphorus

(RDA) Recommended dietary allowance

(Na) Sodium

(NaOH) Sodium hydroxide

(H_2SO_4) Sulphuric acid

(TRIS) Tris-hydroxy-methyl-aminomethane

(VAD) Vitamin A deficiency

(Zn) Zinc

ABSTRACT

Leafy vegetables provide valuable nutrients to humans. Indigenous or traditional vegetables are rapidly being replaced by exotic plants. These vegetables are often costly and not easily available to communities. This study was undertaken to determine the nutritional composition of the leaves of twenty traditional leafy vegetables namely *Solanum nigrum, Physalis viscosa, Cucumis metuliferus, Momordica balsamina, Amaranthus spinosus, Amaranthus hybridus, Amaranthus dubius, Asystasia gangetica, Justicia flava, Emex australis, Oxygonum sinuatum, Bidens pilosa, Cleome monophylla, Portulaca oleracea, Wahlenbergia undulata, Senna occidentalis, Chenopodium album, Ceratotheca triloba, Galinsoga parviflora* and *Centella asiatica* from different locations in Kwa-Zulu Natal. The leafy vegetables were analysed for protein, moisture, fat, fibre, carbohydrates, ash, energy values and nutritionally valuable mineral elements (Ca, P, Na, Zn, Mg, Mn and Fe).

The mean energy value ranged from 99.38 kJ 100 g^{-1} in *Portulaca oleracea* to 353.93 kJ 100 g^{-1} in *Senna occidentalis* with an average value of 206.28 kJ 100 g^{-1}. Most of the leafy vegetables contained appreciable quantities of protein with *Senna occidentalis* providing the most abundant source of protein followed by *Amaranthus hybridus*, *Physalis viscosa*, *Momordica balsamina* and *Wahlenbergia undulata*. Three leafy vegetables namely *Centella asiatica*, *Senna occidentalis* and *Ceratotheca triloba* stand out as being very good sources of fat. On average the leafy vegetables contained 2.07 g 100 g^{-1} fibre (range 1.21 – 2.92 g 100 g^{-1}) and 2.74 g 100 g^{-1} ash (range 1.74 – 4.91 g 100 g^{-1}). The carbohydrate content of the leafy samples varied considerably.

All the leafy vegetables assessed contained remarkably high concentrations of calcium, and the richest source was found in the leaves of *Galinsoga parviflora*. The phosphorus content of the leaves varied significantly with the highest value found in *Asystasia gangetica*. Noteworthy was the outstanding sodium concentration in the leaves of *Oxygonum sinuatum* and *Asystasia gangetica*. The highest quantity of copper was found in the leaves of *Bidens pilosa*, followed by *Centella asiatica*, *Solanum nigrum* and *Justicia flava*. The richest source of zinc was found in the leaves of *Chenopodium*

album followed by *Amaranthus dubius* and *Portulaca oleracea* whilst the poorest source was *Ceratotheca triloba*. All the leafy vegetables assayed were excellent sources of magnesium with *Wahlenbergia undulata* containing the highest concentration. *Amaranthus dubius* was found to be the richest source of manganese content. The leaves of *Solanum nigrum* are outstanding in terms of iron content whilst other good sources of iron were found in the leaves of *Portulaca oleracea*, *Oxygonum sinuatum* and *Amaranthus spinosus*.

A comparative study was conducted to compare the results of the five commonly eaten leafy vegetables evaluated in this study namely *Solanum nigrum*, *Amaranthus spinosus*, *Amaranthus hybridus*, *Amaranthus dubius*, *Asystasia gangetica* and *Portulaca oleracea* to published values of these plants. Results indicate that the proximate analyses determined in this study for most of the plants were higher or equivalent to the values obtained for the published results. All the plants analysed in this study contained much higher mineral concentrations when compared to the published results of traditional leafy vegetables.

The results of this study provide information of twenty traditional leafy vegetables which have a higher potential of nutrients as compared to commercially grown crops. These data provides evidence that local crops could be important contributors in the diets of rural and urban people. From this study, twelve leafy vegetables namely, *Cucumis metuliferus*, *Momordica balsamina*, *Justicia flava*, *Asystasia gangetica*, *Amaranthus dubius*, *Amaranthus hybridus*, *Amaranthus spinosus*, *Cleome monophylla*, *Galinsoga parviflora*, *Ceratotheca triloba*, *Wahlenbergia undulata* and *Physalis viscosa* provide valuable sources of protein and minerals and are thus recommended for extensive cultivation. Communities should be informed about the benefits of these nutritionally important leafy vegetables.

CHAPTER ONE: INTRODUCTION AND LITERATURE REVIEW

1.1 INTRODUCTION

South Africa has great cultural diversity, with many people still using a wide variety of plants in their daily lives for food, water, shelter, fuel, medicine and other necessities of life (Van Wyk and Gericke, 2000). These plants, often referred to as traditional vegetables account for 10% of the world's higher plants. According to the FAO (1988), traditional vegetables are all categories of plants whose leaves, fruits or roots are acceptable for use as vegetables. However, they are underutilised in favour of introduced exotic vegetables (Rubaihayo, 1992). In recent years, exotic vegetables have taken prominence over indigenous vegetables, in spite of their generally lower nutritive value. The availability of indigenous vegetables has declined drastically because of excessive cultivation of field crops, which includes chemical elimination of wild vegetables and habitat change. There is also growing ignorance among young people about the existence of these nutritionally rich plant foods.

This decline in the use of indigenous vegetables by many rural people has resulted in poor diets and increased incidence of nutritional deficiency disorders and diseases in many parts of Africa (Kwapata and Maliro, 1995). The World Health Organisation has reported that chronic undernutrition affects some 200 million people in sub-Saharan Africa, or 42% of the population. Traditional vegetables represent a cheap but good quality nutrition to the poor section of the population, especially where malnutrition is widespread. Use of indigenous plants by local people is still a relatively under-researched discipline in South Africa. Knowledge of indigenous plant use needs urgent scientific documentation before it is irretrievably lost to future generations (Guarino, 1997).

The aims of this study were to determine the nutritional value of traditional leafy vegetables before and after processing and to assess the nutritive value of foods eaten by the local population. The objectives were: (i) to analyse the energy, protein, fibre, fat, carbohydrate, moisture, ash, vitamin and mineral composition of these leafy vegetables,

(ii) to employ the common processing strategies and thereafter re-analyse the nutritional status of the vegetables and (iii) to compare the nutritional value of selected leafy vegetables to published values of commercial leafy vegetables.

This project was divided into three phases.

The first phase involved the chemical analyses that determined the content of protein, fibre, fat, carbohydrate, moisture, vitamins (A and C) and minerals (calcium, copper, iron, zinc, magnesium, manganese, phosphorus and sodium) of selected leafy vegetables. All analyses conducted were in accordance with the Association of Official Analytical Chemists (AOAC) methods (AOAC, 1990).

The second phase involved the employment of common methods of preparation for consumption and subsequent re-analyses that determined their nutritional status as edible leafy vegetables.

The third phase involved the comparison of the nutritional value of leafy vegetables analysed in this study to published values of leafy vegetables.

1.2 LITERATURE REVIEW

1.2.1 Man's Changing Dietary Patterns

For thousands of years the hunter-gatherer of South Africa has survived on the bounty of grasslands and forests (Jacobs, 2002). Early man, the hunter and food gatherer, must have acquired an immense amount of accurate knowledge about the fauna and flora of their neighbourhood. Although meat was preferred in the drier areas, where game was less plentiful, there was a greater dependence on plants as a source of food. Presumably, it must have been through the hard road of trial and error that man learnt which plants could be eaten; which although inedible, were valuable because of their medicinal properties and which must be avoided because they were poisonous. In time humans even learnt how to remove the toxins present in some otherwise desirable plants so that they could be eaten (Fox and Norwood Young, 1982). Evidence from this and other Old Stone Age societies' sites indicate that early foraging groups had a remarkably varied plant diet.

Modern foraging societies such as the Kung San of the Kalahari Desert of Southern Africa have foraged in this area for at least 10 000 years, continuing the hunter-gatherer way of life until recent times. Extensive studies of the Kung during the 1960s revealed that they utilised over 100 species of plants, with two-thirds of their diet, plant based. The plants included a mixture of fruit, nuts, berries, melons, roots and greenery. The Kung diet was very nutritious. They consumed an average of 2.355 calories per person per day, with 96 g of protein and adequate vitamins and minerals. This more than met the nutritional requirements established for people of the Kung stature and physical activity (Arntzen and Ritter, 1984).

Throughout history edible wild plants have sustained human populations in each of the inhabited continents. The agricultural revolution that began more than 10,000 years ago, created a dramatic shift in the human food supply. One result was a significant reduction in dietary diversity. As humans changed, economically and technologically from hunter-gatherer encampments to settlements, and ultimately to urban living, diets

changed significantly (Grivetti *et al.*, 1980). Food is largely grown by specialists and includes products from near and far (Fox and Norwood Young, 1982).

1.2.2 Dietary Transition in the South African Black Population

The South African population including the African population, ranges from those living near-traditional lifestyles to urban sophisticates, immigrant Indians, Coloureds (of European, Black, Malay, Khoi and San descent), and Whites. Shifts in dietary intake to a less prudent pattern are occurring with apparent increasing momentum, particularly among Blacks that constitute by far the bulk of the population. Macronutrient dietary intake profiles among adults range from prudent among Blacks, to western in other groups (Bourne and Steyn, 2000).

One of the hypotheses supported by rural/urban comparisons of African populations has been that with urban exposure the traditional diet is abandoned for a western diet, typified by decreases in carbohydrate and fibre and increases in fat. The traditional diet is associated with a low prevalence of degenerative diseases, whereas the western diet is associated with an increased prevalence of these ailments (Burkitt, 1982).

Examinations of macronutrient and micronutrient intakes over time from various studies done on blacks are therefore pertinent, representing both urban and rural studies (Albertse *et al.*, 1990; Walker *et al.*, 1992). Despite the variety of methodologies employed, the available data serve to illustrate certain trends, namely that: (i) there is little variation in the proportion of protein intake over time, and between rural and urban areas; (ii) fat intakes show an overall upward trend over time in both rural and urban areas; and (iii) conversely, the proportion of energy derived from carbohydrate decreases in both urban and rural communities (Bourne and Steyn, 2000).

A study conducted by Bourne *et al.* (1993) revealed that large percentages of individuals fell below two-thirds of the recommended dietary allowance (RDA) for several vitamins and minerals, reflecting a nutritionally depleted diet. An evaluation of the dietary pattern indicated a diet confined to a relatively narrow range of foods

(Bourne *et al.*, 1994b). Analyses of food group intake by urban exposure illustrate the backdrop of shifts in food choices behind these macronutrient trends. Moreover, a high prevalence of anaemia, particularly in women (20.8%) as opposed to men (6.3%), reflects the pattern of lower iron intake by women, and in particular the high proportion of women with an iron intake below the RDA. The low vitamin and mineral status not only places many individuals at risk for developing deficiency syndromes, but also compromises their immunity to infections. The collective evidence, therefore, illustrates that there has been a slow shift in the direction of a western diet over time (Bourne and Steyn, 2000).

1.2.3 Essential nutrients for humans

The basic nutritional needs of humans are to supply energy and raw materials for all the various activities and processes that occur in the body. In addition to the need for water, humans require five types of nutrients from their food supply: three of these are required in relatively large amounts and are called macronutrients, consisting of carbohydrates, protein and fat. The other two types of nutrients, vitamins and minerals, are required in small amounts and are known as micronutrients.

If nutritional requirements are not satisfied, deficiency diseases can result with widespread effects in the bodily systems. Plants can supply the majority of human nutritional requirements and there is evidence that increasing the proportion of plant foods in the diet can have positive health benefits (Arntzen and Ritter, 1984).

1.2.3.1 Macronutrients

Human energy requirements vary with the age, sex, and activity level of the individual, within a wide range of 1 200-3 200 calories per day. A calorie is a measure of energy – technically the amount of energy needed to raise the temperature of one gram of water by one degree Celsius. Although all the macronutrients can be used as a source of energy, normally only carbohydrates and fats do so, while proteins provide the raw

materials or building blocks, required for the synthesis of essential metabolites, growth and tissue maintenance (Arntzen and Ritter, 1984).

1.2.3.1.1 Proteins

Proteins are a group of large complex molecules that serve as structural components as well as regulating a great variety of bodily functions (Arntzen and Ritter, 1984). The constituents of proteins are amino acids; there are twenty naturally occurring amino acids in food proteins, and proteins from different foods vary in the number and the sequence of amino acids (Arntzen and Ritter, 1984). All twenty amino acids are necessary for protein synthesis, and cells in the human body have the ability to synthesize eleven amino acids from raw materials, the other nine cannot be made by the body. These nine are called essential amino acids and must come from the diet. Essential amino acids cannot be stored by the body and these must be present simultaneously in the diet. For this reason it is critical that the body receives all the essential amino acids in a single meal. Persistent lack of these essential amino acids prevents synthesis of necessary proteins and results in protein deficiency diseases.

Proteins derived from plants are usually incomplete, deficient in one or more essential amino acids and therefore, by combining complementary plant proteins, the essential amino acid requirements can be met. It is recommended that approximately 12% of our total calorie intake be provided by proteins (Arntzen and Ritter, 1984).

1.2.3.1.2 Fats

Fats are usually considered the culprits in the diet, leading to obesity and cardiovascular disease, but some fat is necessary since it serves several vital functions. Fats and related compounds belong to a larger category of organic molecules called lipids. Ninety-five percent of the lipids in foods are fats and oils; both of these compounds are chemically classified as triglycerides. Fatty acids themselves are the simplest type of lipid and serve as building blocks for triglycerides and phospholipids (Arntzen and Ritter, 1984).

1.2.3.1.3 Fibre

Fibre is derived from plant sources and although not digestible, it does provide bulk and many benefits. There are many different types of dietary fibre: cellulose, lignin, hemicellulose, pectin, gums, mucilages, and others. Cellulose, a principal component of plant cell walls, is another polysaccharide composed of glucose, unlike starch and glycogen. However, humans do not have the enzymatic ability to break the bonds connecting glucose molecules and thus cellulose passes through the digestive tract as roughage, largely unaltered. Dietary fibre can be conveniently grouped into two types: soluble and insoluble, relating to their relative solubility in water. Insoluble fibre includes cellulose, lignin, and some hemicelluloses, while soluble fibre includes other hemicelluloses, pectins, gums, mucilages, and the algal polysaccharides. Fruits, vegetables, seeds and whole grain supply most of the fibre in the human diet (Arntzen and Ritter, 1984).

1.2.3.1.4 Carbohydrates

Although carbohydrates are commonly grouped into sugars and starches, these compounds can be chemically classified into monosaccharides, disaccharides and polysaccharides, based on the number of sugar units in the molecule. Monosaccharides are the basic building block of all carbohydrates and glucose is the most abundant of these sugars. Disaccharides are composed of two monosaccharides chemically joined together. The most common disaccharide is sucrose. Polysaccharides, also known as complex carbohydrates, contain hundreds to thousands of individual sugar units, and for the most part, glucose is the only monosaccharide present. Starch is the storage form of glucose found in plants occurring abundantly in seeds, some fruits, tubers and taproots. The presence of starch in foods can be traced directly to its plant origin (Arntzen and Ritter, 1984).

1.2.3.2 Micronutrients

Micronutrients are essential for proper nutrition but are required in much smaller amounts. There are two categories of micronutrients, the organic compounds known as vitamin and the inorganic compounds, the minerals (Arntzen and Ritter, 1984).

1.2.3.2.1 Vitamin A

Vitamin A has many roles in the body. One of the best known involves the formation of visual pigments (retinol) present in the retina of the eye. Vitamin A is an important anti-oxidant, vital for healthy skin and cell membranes, and important for the function of the immune system, amongst other things (Arntzen and Ritter, 1984).

Plants are full of natural pigments called carotenoids, generally referred to as vitamin A (Arntzen and Ritter, 1984). Beta-carotene (β-carotene) is the most important provitamin A source and may serve as an anti-oxidant in the body (Temple and Basu, 1988). In recent years, β-carotene has emerged as a potentially beneficial phytochemical in the light of epidemiological research findings which link the consumption of food products rich in β-carotene to the reduction in risk of developing certain types of cancers (Steinmetz and Potter, 1996).

β-carotene is converted to vitamin A by the body. Because the rate at which β-carotene is converted to vitamin A in the body is known, most often vitamin A content of foods is quoted as 'actual' vitamin A (retinol); generally the number of micrograms per 100 gram sample, and the micrograms of β-carotene are converted into International Units of vitamin A (The Natural Food Hub, 1996).

Epidemiological studies suggest that the onset of chronic disease states such as coronary heart disease, certain cancers and macular degeneration can be reduced by high dietary intakes of carotene-rich foods (Sies and Krinsky, 1995). Vitamin A supplementation among communities at risk of deficiency effectively reduces mortality and morbidity in

children younger than age 5, and vitamin A may be especially effective in HIV-infected children (Duggan and Fawzi, 2001).

1.2.3.2.2 Vitamin C

The most important role of vitamin C in the body is in the synthesis of collagen, a connective tissue protein that serves as a 'cellular cement' holding cells and tissues together. Collagen, the most abundant protein in the body, is found in the matrix of bones, teeth and cartilage and provides the elasticity of blood vessels and skin. Vitamin C also functions as an anti-oxidant in the body, preventing other molecules from being oxidised (Arntzen and Ritter, 1984).

1.2.3.2.3 Calcium

Calcium (Ca) is required for bone and tooth formation and maintenance, normal nerve transmission, muscular growth, permeability of cell membranes and helps keep the immune system healthy. It prevents and treats osteoporosis, relieves muscular cramps and helps relax muscles. A deficiency of calcium results in stunted growth in children and osteoporosis in adults (Arntzen and Ritter, 1984).

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1.2.3.2.4 Copper

The adult human body contains about 1.5±2.0 ppm of copper (Cu) (Kies, 1989), which is essential as a constituent of some metalloenzymes and is required in haemoglobin synthesis and in the catalysis of metabolic oxidation (Schroeder, 1973; Underwood, 1977 – cited by Onianwa *et al.*, 2001). Symptoms of copper deficiency in humans include bone demineralisation, depressed growth, depigmentation, and gastro-intestinal disturbances, among others, while toxicity due to excessive intake has been reported to cause liver cirrhosis, dermatitis and neurological disorders (Graham and Cordano, 1976; Lucas, 1974; Somer, 1974 - cited by Onianwa *et al.*, 2001).

1.2.3.2.5 Iron

Iron (Fe) is used in the formation of haemoglobin in the blood. This mineral is involved in cellular energy production. Iron deficiency results in anaemia, weakness, fatigue, infections and reduced resistance to cold temperatures (Arntzen and Ritter, 1984).

1.2.3.2.6 Magnesium

Magnesium (Mg) is required to improve the strength of bones and teeth. It activates enzymes needed to release energy in the body. Magnesium prevents nervousness, muscular tenseness and cramping (Arntzen and Ritter, 1984).

1.2.3.2.7 Manganese

Manganese (Mn) activates many enzyme reactions and fat and carbohydrate metabolism. This mineral acts as an antioxidant and helps generate normal muscle contraction (Arntzen and Ritter, 1984).

1.2.3.2.8 Phosphorus

Phosphorus (P) helps to build bones and teeth, regulate energy metabolism, assist with release of energy from food and maintain the acid-base balance. A deficiency of phosphorus results in weakness, bone pain and appetite loss (Arntzen and Ritter, 1984).

1.2.3.2.9 Sodium

Sodium (Na) helps with fluid and electrolyte balance, muscle relaxation, regulation of blood pressure and transmission of nerve impulses. A deficiency of sodium results in muscle cramps, appetite loss and mental disorders (Arntzen and Ritter, 1984).

1.2.3.2.10 Zinc

Zinc (Zn) constitutes about 33 ppm of adult body weight and is essential as a constituent of many enzymes involved in a number of physiological functions, such as protein synthesis and energy metabolism (Fairweather-Tait, 1988). Zinc promotes cell reproduction, tissue growth and tissue repair. It is involved with insulin, immune system, vitamin A transport, taste perception, wound healing and manufacturing genetic material and protein. Zinc is part of over 100 enzyme systems that are essential to digestion and metabolism. A deficiency of zinc results in growth retardation, impaired collagen formation, diarrhoea, nausea, weight loss, night blindness and impaired immune system (Arntzen and Ritter, 1984).

1.2.4 Deficiency Diseases

Protein energy malnutrition is a condition that results from a lack of protein, energy-giving foods and other nutrients in the diet. It may manifest itself as marasmus (where a child is severely wasted), as kwashiorkor (where the child appears oedematous), or a combination of the two conditions (WHO, 1982).

Studies conducted in South Africa showed that: (i) one in five South African children are physically stunted i.e. chronically undernourished due to malnutrition; (ii) children surveyed in Cape Town reflected a profile of growth retardation and wasting (Bourne *et al.*, 1994a); (iii) about 12 cases of marasmus or kwashiorkor have been recorded every month by one feeding scheme in Alexandra township; (iv) one in ten children admitted to Africa's largest hospital, Soweto's Chris Hani Baragwanath, suffers from severe malnutrition; and (v) half of the 3120 children surveyed in a national food consumption survey were found to have less than half the recommended level of nutrients such as calcium, iron and zinc. In 1999, a Health Department survey showed that 21.6% of all South Africans between the ages of one and nine were stunted because of malnutrition, with acute wasting running at 3.7% in the same age group (Schmidt *et al.*, 2002). Depending on the nutrient and the severity of deficiency, the consequences of

malnutrition may include stunted growth, anorexia, susceptibility to infections, behavioral changes and learning disabilities (Klugman, 2002).

Vitamin A deficiency (VAD) is the leading cause of preventable blindness in children and raises the risk of disease and death from severe infection. In pregnant women, VAD causes night blindness and may increase the risk of maternal mortality. Vitamin A deficiency is a public health problem in 118 countries, especially in Africa. For children, lack of vitamin A causes severe visual impairment and blindness, and significantly increases the risk of severe illness, and even death, from such common childhood infections as diarrhoea and measles (WHO, 2003).

A study conducted by Blaauw and Labadarios (1999) in the Western Cape revealed that xerophthalmia was present in 1% of pre-school children, with night blindness in particular found in 14% of them. For pregnant women in high-risk areas, VAD occurs especially during the last trimester when demand by both the unborn child and the mother is highest. The mother's deficiency is demonstrated by the high prevalence of night blindness during this period. VAD may also be associated with elevated mother-to-child HIV transmission (WHO, 2003). Deficiency of β-carotene, the most potent provitamin A carotenoid, can result in xerophthalmia, blindness and premature death (Mayne, S.T. – cited by Fraser *et al.*, 2001).

Iron deficiency is estimated to affect about 30% of the world population (WHO, 1992), making iron by far the most deficient nutrient worldwide. Stephenson (1995) reported that approximately two billion people worldwide are classified as being anaemic, with iron deficiency being considered to be the principal cause. According to the National Food Consumption Survey (Labadarios, 2000), anaemia is a widespread micronutrient deficiency in South Africa and affects between 20% and 30% of young children. Rural children and mothers with limited education are most affected.

The major consequences are poor pregnancy outcome, including increased mortality of mothers and children, reduced psychomotor and mental development in infants,

decrease immune function, tiredness and poor work performance (Cook *et al.*, 1994 – cited by Lucca *et al.*, 2001).

1.2.5 Factors Influencing Underutilisation of Wild Crops

Traditional vegetables have important merits, which include the following considerations: nutritional value, ecological value, agronomic value, food security, cultural value and employment opportunities. Despite these important merits, traditional vegetable research has been neglected, by both the indigenous and the scientific communities and their use is declining. Many leafy vegetables in sub Sahara Africa represent an important component of the daily diet of millions of peoples (Guarino, 1997) but their poor marketing conditions make them largely underutilized in economic terms (Padulosi *et al.*, 2002).

For many species of local importance, the knowledge of the distribution of their genetic diversity and use is still largely limited. Increased reliance on major food crops has been accompanied by a shrinking of the food basket which humankind has been relying upon for generations (Prescott-Allen and Prescott Allen, 1990). This "nutritional paradox" (Ogle and Grivetti, 1985a) has its roots in the agricultural "simplification," a process that favoured some crops instead of others on the basis of their comparative advantages for growing in a wider range of habitats, their simple cultivation requirements, easier processing and storability, nutritional properties and taste (Padulosi *et al.*, 2002).

Mnzava (1995) reported that some of the reasons for the neglect of traditional vegetables include: (i) a lack of demand due to the consumption of modern exotic species; (ii) their status as food eaten by poor people; (iii) their localised importance in certain communities or regions; (iv) abandonment of traditional ways due to urbanization; (v) the large number of species involved; (vi) their status as wild weeds or wild species has led to them not being carefully planted or conserved; and (vii) lack of knowledge of their benefits especially their nutritive value.

1.2.6 Value of Traditional Vegetables

Traditional vegetables are adapted to local agro-ecological conditions, require a minimum of cultivation, can be grown in home gardens, give high yields within a short period, and are easy to harvest and preserve (Mnzava, 1993). Traditional plant species that are utilized as vegetables range from wild to cultivated species with varying categories of domestication which includes: wild and harvested in time of food scarcity; wild but regularly harvested; semi-wild, partly protected or harvested from fallow land and cultivated in mixtures (Okigbo, 1990).

1.2.6.1 Sources of food

Traditional and indigenous leafy plants multiple roles in the diet, not just as unique carriers of certain nutrients, but also adding flavour, colour, and texture that relieve the monotony of an otherwise bland starchy diet (Mnzava, 1995). Green vegetables are important sources of food in southern Africa. They may be eaten fresh, but are more often used as pot herbs (Van Wyk and Gericke, 2000). Leaves and tender shoots of traditional plants are widely used as vegetables and serve as direct food sources (Gbile, 2000).

Traditional vegetable crops are used to help pregnant women to recuperate well after delivery (Edmonds and Chweya, 1997) and help nursing mothers build up their milk supply (Maundu, 2001). Thomo and Kwapata (1984) reported that potash (which is a filtrate collected from ashes of dried amaranth or bean plants) or soda, and groundnut paste are added to certain edible plant leaves. These additives add taste and flavour to the diets.

1.2.6.2 Nutritional value

On the basis of nutritional function, traditional vegetables are classified as secondary food crops (Trudge, 1988). Indigenous vegetables contribute greatly to the nutritional well being of rural people by providing the essential nutrients for body growth and

development and the prevention of diseases associated with nutritional deficiencies. As a group, they provide improved nutrition for people of all economic levels and are important sources of income for subsistence farmers (Mnzava, 1995). In African diets, the traditional use of dark green leaves and certain wild green leaves are the most valuable vegetables because they contain far more carotene and vitamin C, as well as more protein, calcium, and iron than pale green leaves and other vegetables (Latham, 1970).

1.2.6.3 Medicinal and cultural uses

Indigenous medicinal plants are used by more than 60% of South Africans in their health care needs or cultural practices. Approximately 3 000 species are used by an estimated 200 000 indigenous traditional healers (Van Wyk *et al.*, 1997). This implies a tremendous demand for indigenous medicinal plants. Indigenous plants should therefore be protected as a source of both food and medicine (Venter *et al.*, 2000).

The same compounds as are present in medicinal plants may equally be found in vegetables. Some of our vegetables had originally been used as medicinal plants; the boundaries between medicinal and vegetable plants are fluent. Breeding measures to establish resistance properties into new cultivars have to attend to such medicinally effective (e.g. semi-essential) substances. Parts of vegetables may be used to produce drugs, or may be effective via dietetic food. Anticarcinogenic substances as proved in some vegetable species may also get more and more importance (Fritz *et al.*, 1993).

Due to urbanisation, a large informal trade business has been established with medicinal plants. Unfortunately, utilization of the plants has depleted some wild populations, resulting in many plant species being considered vulnerable, and being lost from their natural habitat. If raw materials from medicinal plants can be delivered in sustainable quantities (Mander *et al.*, 1995), indigenous plants will continue to form an important component of the primary health care in Southern Africa (Coetzee *et al.*, 1999).

1.2.6.4 Rural and economic value

Despite South Africa's enormous richness in plant species, relatively few of these plants are economically utilized. Business ventures that have developed from the use of indigenous plants are the trade in medicinal and cultural plants, food crops, and ornamental plants. South Africa beholds her indigenous plants as a valuable natural resource and accepts responsibility to conserve the unique flora. Attempts are also made to utilize the plant kingdom economically for the nation, but with legal acknowledgement of the legal owners (Coetzee *et al.,* 1999).

Wild plants continue to provide a wide range of items for home use in many rural communities in southern Africa ranging from drying racks for pots and pans, axe and hoe-handles, grain stamping mortars or general purpose rope (Cunningham, 1987). Although over 100 indigenous plant species are used as traditional dyes and fibres for basketry in southern Africa (Cunningham, 1987; Shaw, 1992), three plant genera *Hyphaene* palms, *Berchemia discolor*, *Euclea* spp. (five species) are the major plant resource base of most basket production in the region (Cunningham, 1987).

Indigenous edible plants are found on sale as vegetables in both rural and urban markets in Africa, (Edmonds and Chweya, 1997). In addition to barter or trade of plant resources at a homestead level, sales of crafts, medicinal plants and bush-foods commonly take place at roadside stalls, cattle auctions, bus stops and taxi ranks (Cunningham, 1987). The plants are therefore important in income generation within the subsistence production sector. Numerous surveys provide evidence that indigenous vegetables offer a significant opportunity for the poorest people to earn a living, as producers and/or traders, without requiring large capital investments (Schippers, 2000).

The volume of production and the number of traders of indigenous vegetables have increased in response to growing urban populations. However, this may also be because the economic crisis has forced consumers to switch to cheaper alternatives in their diets, i.e. from meat and fish products to a higher vegetable diet. Lower capital requirements

make the indigenous vegetable market highly competitive, which may imply lower profits (Schippers, 2000).

Within the African region, there are several categories of plants that could generate income and employment, either from wild harvest or developed as new crops (Schippers, 2000).

1.2.7 The Role of Wild Vegetables in Food Security

From time immemorial, edible wild fruits and vegetables have played a very vital part in supplementing the diet of the people of the world. In tropical Africa, the wild or cultivated nature of many food plants varies with distance from the homestead. The same herb or tree maybe planted near the house, protected if it appears in a field and harvested from wild stands farther away (Okigbo, 1977 – cited by Barrett, 1990). Some species are not cultivated, but there is no need when the wild plants are plentiful. In many tropical regions gathered wild vegetables are very important in the diets of rural people, especially seasonally (Becker, 1983).

The degree of dependence on these wild fruits and vegetables has gradually declined as more exotic fruits and vegetables have been introduced. Although the use of wild vegetables has recently decreased, many people in rural areas still use them extensively as a supplement to their basic food requirements; some are preserved for use during periods of scarcity (Manyafu, 2000). Many are marketed, providing cash income to the harvester and relatively inexpensive vegetables to the public (Bittenbender *et al.*, 1984). Although the popularity of these wild forms of vegetables has declined, it is considered that special attention should be paid to them in order to maintain and improve this important source of food supply. Apart from their traditional use as food, these indigenous vegetables have potentially many advantages over the exotic types, namely:

1. They are already adapted to the local environment.
2. They are generally more nutritious.
3. They are often immune to diseases.

4. They are less adversely affected by insect attack than exotic types.
5. They are adapted to withstand competition with other plants and weeds.

Despite these advantages, some plant species which have been used as vegetables are on the verge of extinction due to the inevitable changes occurring in the ecology of many areas (Manyafu, 2000).

Many studies illustrate the great importance of wild spinaches in the diet of rural people (Ogle *et al.,* 1990; FAO, 1986). Popular wild spinaches used widely in southern Africa are *Amaranthus* species (*A. hybridus, A. spinosus*) (Amaranthaceae), *Pentarrhinum insipidum* (Asclepiadaceae), *Cleome gynandra* (Capparaceae), *Corchorus* species (*C. tridens* and *C. trilocularis*) (Tiliaceae) and the introduced *Bidens pilosa* (Asteraceae). Wild spinaches were similarly reported as the main side to porridge in savanna areas of Swaziland by 39% of 133 meals surveyed (Ogle and Grivetti, 1985a). A similar situation applies on the Maputaland coastalplain, where wild plants appeared in 32% of all meals, and 81% of vegetable side dishes comprised wild species, and 17.7% of introduced or cultivated vegetables (Ogle and Grivetti, 1985a). Ironically, most of the plant species providing this nutritionally important food resource are considered useless weeds by commercial farmers (Cunningham, 1988).

1.2.8 Description of Leafy Vegetables Used in this Study

Edible wild leafy vegetables play an important role in African agricultural and nutritional systems but they are regarded by scientists as minor crops and hence receive little attention in most research and development programs. This study is based on the nutritional value of the following indigenous and local plants. Information was extracted from Fox and Norwood Young, 1982 unless otherwise stated.

1.2.8.1 *Solanum nigrum*

1.2.8.1.1 Plant classification

Family: Solanaceae

Genus: *Solanum*

Species: *nigrum*

Common names:

English: black nightshade, common nightshade, deadly nightshade, garden nightshade, hound's berry, nightshade, pretty morel, stubbleberry.

1.2.8.1.2 Description

Erect, branched, annual herb or biennial, up to 40 cm high with usually angled and grooved stems. Leaves alternate, petiolate, bright green on both surfaces. Flowers 4-6 mm long with white petals, and conspicuous yellow stamens, arranged in few-flowered umbel-like, drooping inflorescences. Fruits spherical berries, black when ripe with many yellow to brown lenticular seeds.

Fig. 1.1 *Solanum nigrum*

1.2.8.1.3 Distribution

A common cosmopolitan weed found throughout South Africa, Namibia, Swaziland, Lesotho and Transkei.

1.2.8.1.4 Edible uses

The leaves of this plant are commonly used as a potherb. The plant may be used dry or fresh. In Lesotho and the Free State, the southern Sothos eat the boiled leaves or the whole young plant as a relish with cereals. Swazis eat the fresh boiled leaves as a relish to other foods as do the Zulus (Fox and Norwood Young, 1982). During the dry season, the leaves must be boiled twice, the water of the first boiling being bitter. The leaves may be cooked with those of *Cleome gynandra* or *Amaranthus* and flavoured with peanut butter (Tredgold, 1986). Thomo and Kwapata (1984) reported that potash, groundnut paste and salt are added to boiled leaves. These additives add taste and flavour to the diets. The ripe fruit is also eaten extensively by the African population.

1.2.8.1.5 Other uses

Solanum nigrum provides a source of income for rural farmers and are sold in both rural and urban markets in Africa. In some districts of South Africa, Zulu women often take baskets of berries to sell in nearby villages or townships (Edmonds and Chweya, 1997). The dark purple juice of the fruit is used as ink (Dokosi, 1998).

1.2.8.1.6 Toxicity

A variety of alkaloids (atropine-like), and glycoalkaloids are found in the nightshades, especially in the green parts of the plant and the unripe fruits. The widely reported toxicity of *S. nigrum* has been attributed to the alkaloid solanine causing varying degrees of poisoning in humans and animals, with death resulting in some cases in townships (Edmonds and Chweya, 1997). The unripe berries have been reported to be poisonous (Tredgold, 1986).

However, the comparable number of accounts reporting that these species are harmless as food and fodder sources suggest that this toxicity is variable. Schilling *et al.* (1992) concluded that the plants are probably only poisonous to indiscriminate feeders such as livestock who might consume the whole plant. Rogers and Ogg (1981) suggested that the development of toxic levels of these alkaloids is dependent on their growth under certain conditions or in certain localities, and even on the age of the plants concerned. Other reports suggest that the amounts of poisonous 'principles' vary greatly with climate, season and soil type (Cooper and Johnson, 1984).

The effects of solanine poisoning in humans are reported to be nausea, vomiting, diarrhoea, colic, headache, dizziness, loss of speech, fever, sweating, mental confusion, convulsions, coma and death (Cooper and Johnson, 1984).

1.2.8.2 *Physalis viscosa*

1.2.8.2.1 Classification

Family: Solanaceae

Genus: *Physalis*

Species: *viscosa*

Common Names:

English: grape ground-cherry, sticky gooseberry, prairie ground-cherry (Hendersen and Anderson, 1996).

1.2.8.2.2 Description

Erect to decumbent, branched perennials up to 30 cm high, with extensive underground rhizomes. Stems are terete to angled, densely, shortly glandular pubescent and green. Leaves are alternate or ovate to elliptical, up to 6 cm long, 3 cm broad, often unequally decurrent on the petiole at the base, petioles about 1 cm long, margins entire or remotely dentate, both surfaces yellowish green, densely glandular-pubescent. Flowers are

solitary, axillary on slender pedicels up to 1-5 cm long, calyx green, glandular about 6 mm long, corolla campanulate with lobes spreading to 2 cm diameter, yellow, sometimes with green or yellow marks in the throat. Fruits are enclosed in inflated membranous calyces up to 2-5 cm long, globose yellowish berries, 1-2 cm diameter containing many seeds. Seeds are yellowish brown, lenticular, 1mm diameter with finely pitted testas (Hendersen and Anderson, 1996).

1.2.8.2.3 Distribution

This plant is found growing in lands, gardens and roadsides in South Africa. Common in Kwa-Zulu Natal, the Free State, Gauteng and the Cape (Hendersen and Anderson, 1996).

Fig. 1.2 *Physalis viscosa*

1.2.8.2.4 Edible uses

Physalis viscosa is an important indigenous plant used in the Transkei region as a food supplement (Fox and Young, 1982). The fruit or berries are slightly acid and edible, with a faint bitterness (King's American Dispensatory, 1992).

1.2.8.3 *Cucumis metuliferus*

1.2.8.3.1 Classification

Family: Cucurbitaceae

Genus: *Cucumis*

Species: *metuliferus*

Common Names:

English: horned cucumber, bitter wild cucumber, jelly melon (Fox and Norwood Young, 1982), kiwano, melano, African horned cucumber, jelly melon, hedged gourd, horned melon, English tomato (Benzioni, 1998).

1.2.8.3.2 Description

An annual herbaceous climber with long slender stems several meters long, longitudinally furrowed, stiffly patent, hairy. Tendrils are slender and simple, in the axils of the leaves. Leaves long-stalked, cordate with a large basal sinus, dark green, silky hairy, shallowly 3-5-lobed. Flowers unisexual, on the same plant, the male flowers 5-6 mm long, solitary or in fascicles, yellow, the female flower solitary, yellow. Fruit are sub-cylindrical, ovoid or ellipsoid, at first mottled dark green, when ripe orange-red and about 60 mm in diameter by 120 mm long, thinly covered with blunt stout spines.

Fig. 1.3 *Cucumis metuliferus*

1.2.8.3.3 Distribution

The plant is widely but sparsely distributed in Namibia, Botswana, Gauteng, Kwa-Zulu Natal, Cape Province and Zimbabwe. The jelly melon is widely cultivated but it is also found wild northwards from Gauteng and Namibia, common in old lands and on roadsides in Zimbabwe. The wild form is a climber over bushes and trees.

1.2.8.3.4 Edible uses

This plant is said to be fairly popular with the African community in the Transvaal district in times of famine, when it is cooked as spinach sometimes mixed with other wild plants or with mealie meal. In Malawi, the leaves are cooked as a side dish. In Zimbabwe, the new leaves are stripped from the stems and washed, and boiled as spinach with the addition of groundnuts or peanuts (Tredgold, 1986). It is said that the cucumber-like fruit is rather bitter and is seldom eaten except in times of scarcity by Bushmen who roast the fruit and then strain the flesh. Huxley (1992) reported the fruit to be insipid. The peeled fruit are eaten raw in Zimbabwe. They may also be split open, sun dried on both sides to be stored as preserves. The wild cucumber may also be used in salads or pickled in vinegar (Tredgold, 1986).

1.2.8.3.5 Other uses

Cucumis metuliferus is currently being promoted as a speciality fruit for export to the European and USA market (Benzioni, 1998).

1.2.8.3.6 Toxicity

Cucurbitacines are present in some accessions of *Cucumis metuliferus*, making it extremely bitter. These compounds are very toxic to mammals, however as they are the most bitter substances known. They are also feeding deterrents and very rarely eaten by mammals (Benzioni, 1998). The sprouting seed produces a toxic substance in its

embryo (Frohne and Pfänder, 1984). Bitter cucumbers are purgative and emetic, harmful to both human and animals (Tredgold, 1986).

1.2.8.4 *Momordica balsamina*

1.2.8.4.1 Classification

Family: Cucurbitaceae
Genus: *Momordica*
Species: *balsamina*
Common names:
English: balsam-apple, African cucumber, balsamina, balsam pear

1.2.8.4.2 Description

A perennial herbaceous climber arising from a tuberous root-stock, with many lax, slender, smooth stems up to 2 m or longer, longitudinally furrowed. Leaves light green, slightly hairy or smooth, deeply palmately 5-7 lobed to the middle; each lobe irregularly coarsely toothed. Tendrils are slender, simple, glabrous or somewhat hairy opposite the leaves at the nodes. Flowers monoecious, solitary, pale yellow, in the axils of the leaves, 7-15 mm long. Fruit sub-globose to ovoid with a broad conical rostrum, green initially, becoming bright orange to red when ripe, covered with numerous blunt conical spines.

Fig. 1.4 *Momordica balsamina*

1.2.8.4.3 Distribution

Occurs in tropical and sub-tropical Africa extending to north-west India. In South Africa it is found in the Free State, Gauteng, Kwa-Zulu Natal and the Cape Province. Also found in Botswana and Namibia.

1.2.8.4.4 Edible uses

Sothos use the leaves of mohodu as a spinach. From the lower Oliphants River area it is reported that Shangaan use the leaves and green fruits of this creeper, which usually appear after the first spring rains and near streams, as a relish to other food. The leaves and fruit are boiled with a little salt and made into soup which is eaten with porridge; sometimes nkaka is added to ground-nut soup as a flavour. Thongas boil the plant and, after discarding the water, cook it with nuts or mealie meal; sometimes the leaves and green fruits are cooked with crushed groundnuts and used as gravy. When fruits are ripe the seeds are eaten raw. Zulus cook this plant as a vegetable.

1.2.8.5 *Amaranthus dubius*

1.2.8.5.1 Classification

Family: Amaranthaceae
Genus: *Amaranthus*
Species: *dubius*
Common names:
English: wild spinach, spleen amaranth (Plants for a Future, 1997-2000).

1.2.8.5.2 Description

Amaranthus dubius is a simple, annual herb and is frost tender. The flowers are monoecious (individual flowers are either male or female, but both sexes can be found on the same plant) and are pollinated by wind. The plant is self-fertile. The plant prefers

light (sandy), medium (loamy) and heavy (clay) well-drained soil. The plant prefers acid, neutral and basic (alkaline) soils. It cannot grow in the shade. (Plants for a Future, 1997-2000).

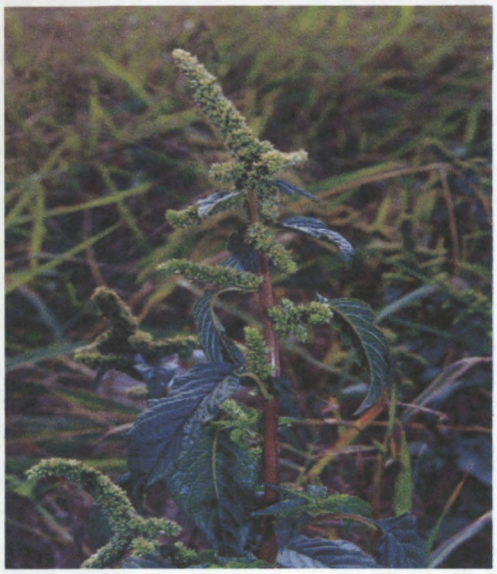

Fig. 1.5 *Amaranthus dubius*

1.2.8.5.3 Distribution

This plant is commonly found in disturbed land, around habitations and occasionally in the savanna, recorded from Sierre Leone and Nigeria and occurring much more widely in the region. It is widespread in tropical Africa and in America (Burkhill, 1985).

1.2.8.5.4 Edible uses

Used as a potherb, they are considered to be very palatable (Facciola, 1990). This herb is cooked and eaten as spinach and is used as a relish (Burkhill, 1985). The seeds are rather small, but very nutritious; it can be ground and used as a powder. The seeds can be cooked whole, and becomes very gelatinous, but it is rather difficult to crush all of the small seeds in the mouth and thus some of the seed will pass right through the digestive system without being assimilated (Plants for a Future, 1997-2000).

1.2.8.5.5 Other uses

Yellow and green dyes can be obtained from the whole plant (Grae, 1974 – cited by Plants for a Future, 1997-2000).

1.2.8.5.6 Toxicity

No members of this genus are known to be poisonous (Plants for a Future, 1997-2000).

1.2.8.6 *Amaranthus hybridus*

1.2.8.6.1 Classification

Family: Amaranthaceae
Genus: *Amaranthus*
Species: *hybridus*
Common Names:
English: cockscomb, Hell's curse, panicled amaranth, pigweed, prince's feather

1.2.8.6.2 Description

An erect, much branched, annual herb up to 1 m high, with stout more or less grooved stems. Leaves simple, alternate, broadly lanceolate tapering to both ends, mucronulate, the margins entire. Inflorescence long and dense, terminal and axillary spikes 5-15 cm long. Flowers monoecious, numerous; female perianth segments 5 with acuminate awns. Fruit small, bladder-like, with small, lenticular, dark red, brown or black shiny seeds.

Fig. 1.6 *Amaranthus hybridus*

1.2.8.6.3 Distribution

A cosmopolitan weed, common throughout South Africa and Namibia. A weed of cultivated and waste ground, probably a native of tropical America.

1.2.8.6.4 Edible uses

This plant produces the best of the amaranth spinaches (Burkhill, 1985). The leaves and young shoots of this plant are widely used as a staple food since they are available from October to March. Commonly they are boiled and eaten as a relish, either alone or mixed with a little mielie-meal to form a green porridge. Sometimes a little fat may be added after cooking; alternatively the cooked leaves may be eaten with milk and salt. The leaves are also frequently dried for use in winter. Facciola (1990) reported that the leaves are cooked as spinach, added to soups or eaten raw. In Zaire, the seeds are prepared into an alcoholic drink (Hauman, 1951 – cited by Burkhill, 1985).

1.2.8.6.5 Other uses

Tredgold (1986) reported that the whole plant is sometimes burnt and the ash used to mix with snuff or in place of salt when cooking other leaves. *Amaranthus hybridus* is an important grain and vegetable crop with considerable economic importance in many parts of the world (Mposi, 1999).

1.2.8.6.6 Toxicity

No members of this genus are known to be poisonous (Plants for a Future, 1997-2000).

1.2.8.7 *Amaranthus spinosus*

1.2.8.7.1 Classification

Family: Amaranthaceae
Genus: *Amaranthus*
Species: *spinosus*
Common names:
English: spiny pigweed

1.2.8.7.2 Description

Amaranthus spinosus is a robust cosmopolitan herb growing to 1 m (Burkhill, 1985). Stems are red with paired, short, sharp, axillary spines. Leaves are ovate or sub-elliptic, 0.5–2.3 cm wide, spikes elongated, mostly paniculate at ends of branches, often with globose, axillary flower-clusters. Flowers are whitish, calyx-segments with sharp spiny tips. Fruits are circumscissile capsules (Dokosi, 1998).

Fig. 1.7 *Amaranthus spinosus*

1.2.8.7.3 Distribution

This plant is commonly found in waste places and clearings and is widespread throughout Africa (Burkhill, 1985).

1.2.8.7.4 Edible uses

Leaves and stems are eaten raw or cooked as a spinach (Kunkel, 1984). If older leaves and stems are used the spines must be removed (Facciola, 1990). The leaves are eaten in all countries, but the plant is seldom cultivated for this purpose. Fox and Norwood Young (1982) reported that although this plant is common in South Africa, it is avoided because of the rough spines which are said to be purgative. Zulus regard it as only a famine food.

1.2.8.7.5 Other uses

A red pigment obtained from the plant is used as a colouring in foods and medicines (Bown, 1995).

1.2.8.7.6 Toxicity

No members of this genus are known to be poisonous (Plants for a Future, 1997-2000).

1.2.8.8 *Asystasia gangetica*

1.2.8.8.1 Classification

Family: Acanthaceae

Genus: *Asystasia*

Species: *gangetica*

Common names:

English: hunter's spinach (Burkhill, 1985), Chinese violet (Smith, 1985).

1.2.8.8.2 Description

An erect, sometimes scrambling perennial herb, tending to be bushy, sometimes slightly woody below. The stems are geniculate below, with branches ascending or erect, irregularly appressed, puberulent, especially at or near nodes, stems somewhat angular or striate. Leaves are thin, ovate to almost orbicular, apex acuminate (Fosberg *et al.*, 1993). Flowers are white with pale purple markings on the lower lip, to 2 cm long, softly pubescent (Dokosi, 1998). Chinese violet is a rapidly growing shrubby herb which grows to 1 m high but can grow over shrubs up to 3 m tall. It can smother all vegetation in the herbaceous layer (Smith, 1985).

Fig. 1.8 *Asystasia gangetica*

1.2.8.8.3 Distribution

Asystasia gangetica is indigenous to India, Malay Peninsula and Africa. This plant grows in the grassland, roadsides and waste places and is widespread throughout Africa (Burkhill, 1985).

1.2.8.8.4 Edible Uses

The leaves are edible though consumption appears to be occasional rather then general (Burkhill, 1985).

1.2.8.8.5 Other uses

The plant is used as a soap substitute (Burkhill, 1985). A weed in the wild but worthy of cultivation as an ornamental plant (Dokosi, 1998).

1.2.8.9 *Justicia flava*

1.2.8.9.1 Classification

Family: Acanthaceae

Genus: *Justicia*

Species: *flava*

Common names:

English: yellow justicia (Pooley, 1998).

1.2.8.9.2 Description

An erect or straggling perennial herb, 90–100 cm high, rooting at nodes. Stems are pubescent and grooved. Leaves are ovate-lanceolate, pubescent, 9-12 cm long, 3-5 cm broad. Spikes are 5-15 cm long and pubescent. Flowers are yellow and dark streaked to 14 mm long (Dokosi, 1998).

Fig. 1.9 *Justicia flava*

1.2.8.9.3 Distribution

This plant occurs throughout Africa (Burkhill, 1985) and grows in moist shady places and grassland areas (Dokosi, 1998).

1.2.8.9.4 Edible uses

It is semi cultivated in parts of Guinea for eating as a vegetable (Busson, 1965 – cited by Burkhill, 1985).

1.2.8.10 *Emex australis*

1.2.8.10.1 Classification

Family: Polygonaceae
Genus: *Emex*
Species: *australis*
Common names:
English: devil's thorn, cat's head, spiny emex

1.2.8.10.2 Description

A tall, erect to semi-erect, much-branched, smooth, annual herb growing up to 60 cm high. Leaves long-stalked, simple, ovate, to oblong, the margins entire to shallowly sinuate. Inflorescence in small, dense axillary panicles. Flowers small 2 mm long, green. Fruit a three-angled nut crowned with three strong, sharp, spreading spines with ovate, veiny, erect wings between.

Fig. 1.10 *Emex australis*

1.2.8.10.3 Distribution

Widespread in South Africa, Namibia and Botswana. It occurs in disturbed sites such as cultivated paddocks, around buildings and along roadsides and in waste places. It is also common in cereal and lucerne growing areas (Land Protection, 2001).

1.2.8.10.4 Edible uses

The young leaves are used as spinach, and it makes tolerably good dish, although slightly aperient.

1.2.8.10.5 Toxicity

The plant also contains oxalic acid, which is toxic, but the weed does not appear to be eaten by animals in large enough quantities to cause poisoning (Fuller, 1998).

1.2.8.11 *Oxygonum sinuatum*

1.2.8.11.1 Classification

Family: Polygonaceae

Genus: *Oxygonum*

Species: *sinuatum*

Common names:

English: Not recorded

1.2.8.11.2 Description

A diffuse, decumbent or erect and weedy annual. Stems glabrous to pubescent, green to reddish brown. Ocreae reddish, up to 5.5 mm long, truncate, usually fringed with setae, the leaf inserted into the upper half and often near the apex. Leaves petiolate, in outline ovate, ovate-elliptic, ovate-lanceolate or elliptic lanceolate, but usually deeply incised with rounded or acute lobes, often panduriform or lyrate, narrowed to each end, commonly 4 × 1.5 cm, usually pustular on the undersurface, otherwise glabrous or shortly pilose on the veins. Petioles are 1-2 cm long. Inflorescence variably elongated, up to 28 cm, the stalk up to 2 mm thick. Flowers white or pink, slightly heterostylous, i.e. long-styled stigmas reaching only to the tips of the anthers or to slightly beyond, and short-styled stigmas reaching to or nearby to the anther bases. Fruit fusiform, 2-4 to each bract, erect or spreading but scarsely pendulous, 5.0-6.5 mm long when mature, pubescent or papillose (Turrill and Milne-Redhead, 1958).

Fig. 1.11 *Oxygonum sinuatum*

1.2.8.11.3 Distribution

This plant is commonly found in eastern Africa from Sudan southwards, Belgian and Congo. Found in cultivated and other ground suited to weed growth (Turrill and Milne-Redhead, 1958).

1.2.8.11.4 Edible Uses

None recorded.

1.2.8.12 *Bidens pilosa*

1.2.8.12.1 Classification

Family: Asteraceae
Genus: *Bidens*
Species: *pilosa*
Common names:
English: blackjack, beggarticks, bur marigold, spanish needles

1.2.8.12.2 Description

An erect, annual herb up to 1.5 m high with glabrous or slightly hairy, quadrangular and grooved stems. Leaves petioled, opposite, variable, pinnate with usually 3-5 leaflets, glabrous or slightly hairy, the margins sharply serrated. Inflorescence a disc-shaped head up to 10 mm in diameter, made up of an outer row of female ray flowers, white or light yellow and inner yellow, bisexual, tubular, disc florets. Fruit black, narrow, ribbed, pappus of two to four awns, retrorsely barbed.

Fig. 1.12 *Bidens pilosa*

1.2.8.12.3 Distribution

A cosmopolitan weed introduced into South Africa and is now widespread in South Africa and Namibia. *Bidens pilosa* is indigenous to the rainforest and other tropical areas of South America, Africa, the Carribean, and the Philippines.

1.2.8.12.4 Edible uses

Reports of the use of this plant as a pot herb have been received from many parts of southern Africa. It is one of the most widely used of the weeds of cultivation. The

young leaves and shoots are preferred as the older leaves have a bitter astringent taste (Fox and Norwood Young, 1982) and are lightly boiled with the addition of peanut butter and salt or potash. They are served as a relish (Tredgold, 1986). Leaves are added to salads or steamed and added to soups and stews (Facciola, 1990). Young shoot tips are used to make a tea (Kunkel, 1984) and also consumed by the African population in Transkei. This is one of the weeds most commonly dried for winter use.

1.2.8.12.5 Toxicity

The roots, leaves and flowers are strongly phototoxic, the achenes weakly so. Substances isolated from the leaves can kill human skin in the presence of sunlight at concentrations as low as 10 ppm (Duke and Ayensu, 1985).

1.2.8.13 *Galinsoga parviflora*

1.2.8.13.1 Classification

Family: Compositae
Genus: *Galinsoga*
Species: *parviflora*
Common names:
English: gallant soldier (Van Wyk and Malan, 1997).

1.2.8.13.2 Description

Galinsoga parviflora is an annual herb up to 2 m tall. The glabrous to pubescent stems are erect and often branched. The ovate to ovate-lanceolate leaves are opposite with short petioles. The leaf blades are sparsely hairy with three prominent nerves, shallowly toothed margins and wedge-shaped bases. The inflorescence is a small head composed of ray and disk flowers. The ray flowers are white usually five in number and lack a pappus. The disk flowers are yellow with a pappus of conspicuously fimbriate scales.

The fruit is a four-angled achene flattened parallel to the involucral bracts (Wagner *et al.*, 1999).

Fig. 1.13 *Galinsoga parviflora*

1.2.8.13.3 Distribution

This plant is an introduced weed in southern Africa and is found growing in arable land, waste places and pavements (Van Wyk and Malan, 1997).

1.2.8.13.4 Edible Uses

The leaves, stem and flowering shoots, raw or cooked are eaten as a potherb, or added to soups and stews. They can be dried and ground into a powder then used as a flavouring in soups. The leaves can also be used as a salad either on its own or mixed with other leaves. The fresh juice can be mixed and drunk with tomato or vegetable juices (Facciola, 1990).

1.2.8.14 *Cleome monophylla*

1.2.8.14.1 Classification

Family: Capparaceae
Genus: *Cleome*
Species: *monophylla*
Common names:
English: spindle-pod (Tredgold, 1986).

1.2.8.14.2 Description

An erect, usually branched, annual herb up to 50 cm tall. Stems striate, often with gland-tipped hairs. Leaves simple, petiolate, hairy on both surfaces. Inflorescence a terminal lax raceme. The petals are pink to male mauve in colour, 3-9 mm long. The fruit is a narrow linear capsule. Seeds small, brown, brown to dark brown, almost circular in outline, somewhat flattened.

Fig. 1.14 *Cleome monophylla*

1.2.8.14.3 Distribution

Common in warm, dry areas of the Gauteng, extending throughout Kwa-Zulu Natal to the eastern Cape Province and northern Namibia. It is also widespread throughout Africa and found in Madagascar, India and Ceylon.

1.2.8.14.4 Edible uses

The young leaves are used in the preparation of a potherb known as morogowa sedalerothane. Blades of older leaves are cooked together with pounded groundnuts and tomatoes to form a side dish. Leaves may be cooked together with the leaves of *Amaranthus* species or *Solanum nigrum* or stewed with cowpeas. The seeds are pounded and used as mustard (Tredgold, 1986).

1.2.8.15 *Portulaca oleracea*

1.2.8.15.1 Classification

Family: Portulacaceae
Genus: *Portulaca*
Species: *oleracea*
Common names:
English: purslane, pigweed, purslain, purslane, pusky, wild purslane

1.9.8.15.2 Description

A prostrate to decumbent, semi-succulent, glabrous, annual herb with numerous spreading, prostrate branches, rather thick, round, reddish. Leaves simple, opposite, wedge-shaped with rounded tips, thick, fleshy and tinged with red. Flowers small, 4-8 mm long, yellow, stalkless, terminal, solitary or up to five. Fruit a flask-shaped, membranous capsule, l-chambered, opening transversely with cap-like top falling off when seeds are ripe. Seeds are numerous, small, black and shiny.

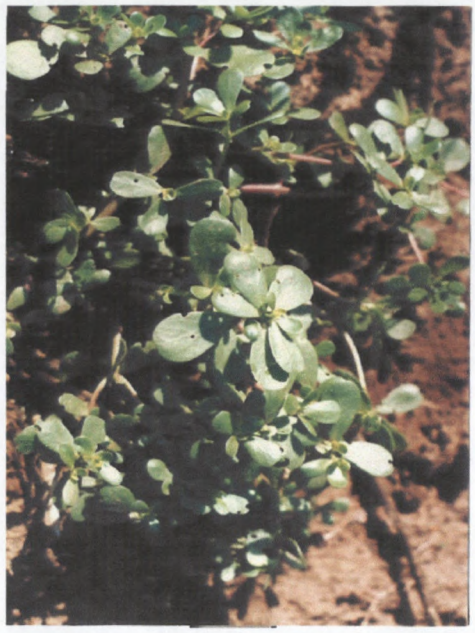

Fig. 1.15 *Portulaca oleracea*

1.2.8.15.3 Distribution

Occurs in the northern, eastern, and central Cape Province, Kwa-Zulu Natal, Transkei, Lesotho, Free State, Gauteng and Namibia. A native of Europe and now a cosmopolitan weed found mainly in gardens and waste places.

1.2.8.15.4 Edible Uses

Portulaca oleracea is eaten as a salad and vegetable all around the world (Leung & Foster, 1996) and this succulent weed is a favourite vegetable in all parts of Southern Africa (Fox and Norwood Young, 1982). Children eat the leaves raw (Van Wyk and Gericke, 2000). Swazis recognise this plant as an imbitvo or green food. The leaves are generally cooked and have a sourish taste. Southern Sothos may sometimes consume up to 90 g of cooked leaves at a time. Zulus consider the ash a substitute for salt. The young plants available from November to February, are cooked and eaten as a vegetable (Fox and Norwood Young, 1982). Their mucilaginous quality also making them a good substitute for okra as a thickener in soups. Older leaves are used as a potherb. The seed

can be ground into a powder and mixed with cereals for use in gruels, bread and pancakes (Facciola, 1990).

1.2.8.15.5 Toxicity

Found to contain up to 9% oxalic acid (dry weight). Prolonged ingestion of the plant was stated to cause inco-ordination of gait and tetanic conditions in sheep (Webb, 1948 – cited by Burkhill, 1997). Oxalates and nor-adrenaline have also been isolated from *Portulaca oleracea* indicating a possible hazard in the taking of its teas (Adams *et al*, 1963 – cited by Dweck, 1998).

1.2.8.16 *Wahlenbergia undulata*

1.2.8.16.1 Plant classification

Family: Campanulaceae
Genus: *Wahlenbergia*
Species: *undulata*
Common Names:
English: Giant bell flower, pale bluebell

1.2.8.16.2 Description

An erect perennial herb up to 60 cm high, from a well developed taproot with much branched slender striate stems covered with scattered white hairs. Leaves simple, lanceolate, acute at the apex, sessile, with scattered white hairs. Leaf margins wavy and shortly toothed. Inflorescence a terminal elongated panicle. Flowers 10-25 mm long, bell-shaped, pale to deep blue. Fruit consists of a dry capsule, splitting lengthwise.

Fig. 1.16 *Wahlenbergia undulata*

1.2.8.16.3 Distribution

Wahlenbergia undulata grows wild throughout the summer rainfall areas of southern Africa. It is quite commonly found in the grassland, usually in rocky or seasonally moist places (Plants for a Future, 1997-2000). This plant is a coastal and mountain grassland species, occurring in the Cape Province, Lesotho, Kwa-Zulu Natal, the Free State, Swaziland and Gauteng. Also found in Mozambique, Zambia and Zimbabwe.

1.2.8.16.4 Edible uses

The leaves are cooked as spinach but they lack bulk and are generally used as a flavouring or addition to other leaves (Tredgold, 1986).

1.2.8.17 *Senna occidentalis*

1.2.8.17.1 Classification

Family: Fabaceae

Genus: *Senna*

Species: *occidentalis*

Common Names:

English: Cassia senna (Hutchings *et al.*, 1996), stinkweed (Leung and Foster, 1996).

1.2.8.17.2 Description

An annual herb or sub-shrub, 0.15-1.8 m high with erect, simple or sparsely branching stems. Stems ridged and glandular. Leaves compound with 4-5 pairs of ovate-elliptic leaflets, the surfaces glandular when young, becoming sparsely glandular when older. Inflorescence a short 2-4-flowered raceme in the axils of the upper leaves. Flowers up to 1.5 cm long, pale yellow with conspicuous brown venation. Fruit a linear straight or slightly curved pod, compressed, green or brown. Seeds compressed, greyish brown.

Fig. 1.17 *Senna occidentalis*

1.2.8.17.3 Distribution

A pan-tropical weed of disturbed areas, usually along river banks, roadsides, old lands or areas of human habitation.

1.2.8.17.4 Edible uses

The genus *Senna* includes 22 trees, shrubs, and herbs used as leafy vegetables (Bittenbender *et al.*, 1984).). In northern Senegal, *Senna occidentalis* grows abundantly during the rainy season and its leaves are consumed in great quantity, as most other foods are scarce at that time. It provides the major source of vitamins A and C, usually being added to millet porridge (Becker, 1983). The roasted seed is used as a coffee substitute although it is said to be toxic before roasting.

1.2.8.17.5 Toxicity

Leaves are toxic only if large quantities are consumed (Russell *et al.*, 1997). Unroasted seeds are toxic.

1.2.8.18 *Chenopodium album*

1.2.8.18.1 Classification

Family: Chenopodiaceae
Genus: *Chenopodium*
Species: *album*
Common Names:
English: fat hen, goosefoot

1.2.8.18.2 Description

An erect annual herb up to 1.5 m tall, with smooth yellowish-green or reddish ribbed stems arising from a stout tap-root. Leaves simple, alternate, long-stalked, lanceolate to ovate, the upper surface green, farinose below, the margins entire to irregularly dentate. Inflorescence a dense many-flowered terminal panicle. Flowers small and green. Fruits small glomerules, surrounded by enlarged perianths. Seeds black, shiny, obtuse margined, usually marked with faint radial furrows.

Fig. 1.18 *Chenopodium album*

1.2.8.18.3 Distribution

A cosmopolitan weed of which the origin is uncertain. It is now widespread in southern Africa, appearing after the first rains. Found commonly on old lands, waste places, on roadsides and gardens.

1.2.8.18.4 Edible uses

This is one of the commonest of the wild spinaches. The fresh leaves and tender tops are boiled and eaten as spinach, or added to mielie meal or yellow meal and eaten as porridge. They are also used as a relish to other foods. The disagreeable smell of the

fresh plant disappears on cooking when it makes a very pleasant dish and is acceptable as a spinach substitute (Facciola, 1990). One report says that, when eaten with beans, the leaves will act as a carminative to prevent wind and bloating (Moerman, 1998). Seeds are dried and ground into a meal and eaten raw (Facciola, 1990). The seed can also be sprouted and added to salads. The seed should be soaked in water overnight and thoroughly rinsed before being used in order to remove any saponins. The seeds may be ground into meal which is baked in cakes and used as a gruel. This herb is sometimes dried for winter use.

1.2.8.18.5 Other uses

A green dye is obtained from the young shoots. The crushed fresh roots are a mild soap substitute (Coon, 1975 - cited by Plants for a Future, 1997-2000).

1.2.8.18.6 Toxicity

Many of the species in this genus contain saponins, though usually in quantities too small to do any harm. Although toxic, saponins are poorly absorbed by the body and most pass straight through without any problem. They are also broken down to a large extent in the cooking process. Saponins are much more toxic to some creatures, such as fish, and hunting tribes have traditionally put large quantities of them in streams and lakes in order to stupefy or kill the fish (Plants for a Future, 1997-2000).

The plants also contain some oxalic acid, which in large quantities can lock up some of the nutrients in the food, but these plants are very nutritious vegetables in reasonable quantities. Cooking the plant will reduce its content of oxalic acid. People with a tendency to rheumatism, arthritis, gout, kidney stones or hyperacidity should take especial caution if including this plant in their diet since it can aggravate their condition (Bown, 1995). There is also a report that very large quantities of the leaves have caused photosensitivity in some people. Only the raw leaves can cause problems, and then only if large quantities are consumed (Schofield *et al.*, 1990).

A further report says that if the plant is grown in soils that contain too much nitrates then the plant can concentrate these substances in the leaves. Nitrates have been shown to cause many health problems including stomach cancers and blue-baby syndrome. In nitrogen-rich soils, the plants can also concentrate hydrogen cyanide in small quantities, hydrogen cyanide has been shown to stimulate respiration and improve digestion, it is also claimed to be of benefit in the treatment of cancer. In excess, however, it can cause respiratory failure and even death (Duke and Ayensu, 1985).

1.2.8.19 *Ceratotheca triloba*

1.2.8.19.1 Classification

Family: Pedaliaceae
Genus: *Ceratotheca*
Species: *triloba*
Common names:
English: wild foxglove (Hutchings *et al.*, 1996).

1.2.8.19.2 Description

An erect perennial plant growing 1-2 m high, with deeply cut lobed leaves, greyish green above and whitish on the underside (Tredgold, 1986). Some plants become quite bushy while others remain single stemmed. The soft, green leaves are about 50 mm long and divided into 3 lobes with a bluntly serrated margin. The leaves are carried on long thin stalks up the stems (Van der Walt, 2001). The large pink or lilac flowers hang downward, the downy bell-shaped throat dividing into five lobes, of which the lowest one is the largest, striped with purple or dark crimson. The fruits are capsules, each with two horns and many small dark seeds within (Tredgold, 1986).

Fig. 1.19 *Ceratotheca triloba*

1.2.8.19.3 Distribution

Ceratoteca triloba is commonly found in the summer rainfall areas of South Africa, especially the grasslands and rocky places, on disturbed ground and often along roadsides (Tredgold, 1986).

1.2.8.19.4 Edible uses

The leaves and new shoots are cooked as spinach. When picked they have an unpleasant rank scent which disappears with boiling. A little salt or potash is added just before serving. The soft slimy product is sweet tasting and easily digestible. It is used as a relish for children and invalids (Tredgold, 1986).

1.2.8.19.5 Other uses

The whole plant soaked in water may be used as a shampoo or soap substitute (Tredgold, 1986).

1.2.8.20 *Centella asiatica*

1.2.8.20.1 Classification

Family: Apiaceae

Genus: *Centella*

Species: *asiatica*

Common Names:

English: marsh pepperwort, pennyworth, waternavel (Fox and Norwood Young, 1982), gotu kola (Plants for a Future, 1997-2000).

1.2.8.20.2 Description

A perennial herb with smooth prostrate branched stems up to 40 cm long, usually rooting at the nodes. Leaves solitary, long stalked, rotund or semicircular. Inflorescence an axillary 1-5 flowered umbel 1-1.5 cm long. Flowers small, bisexual, sub-sessile, smooth, and reddish. Fruit of two slightly swollen brown ribbed mericarps.

Fig. 1.20 *Centella asiatica*

1.2.8.20.3 Distribution

Occurs in damp shaded habitats as well as in water in Botswana, Cape Province, Lesotho, Kwa-Zulu Natal, the Free State, Namibia, Swaziland, Transkei and Gauteng.

1.2.8.20.4 Edible uses

Leaves are cooked like spinach and eaten mixed with mielie meal and a little salt (Fox and Norwood Young, 1982) as well as used in salads and in curries (Bown, 1995). The leaves have been used as a food especially in the Eastern Province among the Xhosa and Mfengu. Among the Xhosas it is only the women who use this herb in their porridge in varying proportions up to an equal quantity of meal. Occasionally the leaves are dried and kept for a season of scarcity.

1.2.8.20.5 Other uses

Extracts of the plant are added to cosmetic masks and creams to increase collagen and firm the skin (Bown, 1995).

1.2.8.20.6 Toxicity

In large doses, this plant is a stupefying narcotic, sometimes producing cephalagia or vertigo with a tendency to coma (Chopra *et al.*, 1949 – cited by Dokosi, 1998).

CHAPTER TWO: MATERIALS AND METHODS

Nutritional analyses (moisture, protein, fat, fibre, ash, vitamin and minerals) were conducted using the leaves of twenty raw leafy vegetables (Table 2.1) and further analyses comprised of cooking five of the most underutilised plant species in order to make comparisons between the raw and cooked vegetable samples. From a literature survey conducted, these twenty traditional leafy vegetables were investigated since they are consumed by the African population and have beneficial properties. The five leafy vegetable species that were cooked were *Amaranthus dubius*, *Oxygonum sinuatum, Wahlenbergia undulata, Galinsoga parviflora* and *Centella asiatica*. Samples were prepared as for raw samples. Prior to analysis each vegetable sample was cooked according to the customary method used by the African population in Kwa-Zulu Natal. A 100 g portion of each plant was boiled for 15 min in 100 ml of water and the resulting cooked samples were subjected to nutritional analyses.

A database of the nutritional value of traditional and indigenous leafy vegetables is being compiled and updated, which includes the previously reported values for protein, fat, fibre, carbohydrate, ash, vitamin and mineral contents. The nutritional values of six leafy vegetables from this study were found in previously published literature and comparisons were made on these leafy vegetables only.

2.1 SAMPLE COLLECTION AND PREPARATION

Twenty traditional leafy vegetables were used in this study. They were collected from different locations in Kwa-Zulu Natal, South Africa. Table 2.1 lists the leafy vegetables used in this study with the following information: scientific name, family, English and Zulu names. These leafy vegetables were identified by a botanist, Professor H. Baijnath, School of Botany and Zoology, University of Durban Westvillle, using available taxonomic keys. The leafy vegetables were brought to the laboratory in refuse bags and were photographed. Herbarium specimens were prepared and will be lodged with the Natal Herbarium, South Africa.

Table 2.1 Details of traditional leafy vegetables analysed

Scientific name	Family	English Name	Zulu Name	Location
Solanum nigrum	Solanaceae	Black nightshade[2]	Umsobo[2]	Reservoir Hills
Physalis viscosa	Solanaceae	Grape ground-cherry[6]	Uqadolo[2]	Park Rynie
Cucumis metuliferus	Cucurbitaceae	Horned cucumber[2]	Uhufafa[2]	Reservoir Hills
Momordica balsamina	Cucurbitaceae	Balsam apple[2]	Inkaka[1]	National Botanical Institute, Durban
Amaranthus spinosus	Amaranthaceae	Spiny pigweed[2]	*	Reservoir Hills
Amaranthus hybridus	Amaranthaceae	Cockscomb[2]	Imbuya[2]	Reservoir Hills
Amaranthus dubius	Amaranthaceae	Wild spinach[3]	*	Reservoir Hills
Asystasia gangetica	Acanthaceae	Hunter's spinach[5]	*	Reservoir Hills
Justicia flava	Acanthaceae	Yellow justicia[4]	Impela[4]	Reservoir Hills
Emex australis	Polygonaceae	Devil's thorn[2]	Inkunzane[2]	Reservoir Hills
Oxygonum sinuatum	Polygonaceae	*	*	Reservoir Hills
Bidens pilosa	Asteraceae	Blackjack[2]	Ilenjane[2]	Reservoir Hills
Galinsoga parviflora	Asteraceae	Gallant soldier[7]	Ushukeyana[7]	Reservoir Hills
Cleome monophylla	Capparaceae	Spindle-pod[8]	Isiwisa[1]	Reservoir Hills
Portulaca oleracea	Portulacaceae	Purslane[2]	Amadilika[2]	Verulam
Wahlenbergia undulata	Campanulaceae	Giant bell flower[2]	Ushwaqa[2]	Reservoir Hills
Senna occidentalis	Fabaceae	Cassia senna[1]	Isinyembane[2]	Reservoir Hills
Chenopodium album	Chenopodiaceae	Fat hen[2]	Imbikilicane[1]	Reservoir Hills
Ceratotheca triloba	Pedaliaceae	Wild foxglove[1]	Udonqa[1]	Reservoir Hills
Centella asiatica	Apiaceae	Marsh pepperwort[2]	Icukudwane[1]	Reservoir Hills

* Not recorded

[1] Hutchings *et al.*, 1996

[2] Fox and Norwood Young, 1982

[3] Plants for a Future, 1997-2000

[4] Pooley, 1998

[5] Smith, 1985

[6] Henderson and Anderson, 1996

[7] Van Wyk and Malan, 1999

[8] Tredgold, 1986

Mature leaves were washed several times with distilled water until no foreign material remained, and air-dried at room temperature for 2 h. Moisture, protein, fat, fibre, ash, vitamin A and C analyses were conducted on fresh leaves that were ground using a mortar and pestle. Samples used for mineral analyses were washed using double deionised water and dried in an air oven for 6 h at 60°C, homogenised using a mortar and pestle and stored in capped bottles in desiccators until analyses were performed. All analyses were conducted in duplicate and results were based on fresh weight per 100 g of sample except for mineral analyses, which was based on dry weight per 100 g.

2.2 ENERGY DETERMINATION

The Atwater system was used to determine the energy values. This system uses factors to estimate available energy from the protein, fat, carbohydrate, and alcohol components of food items. Energy was calculated using the general Atwater's factors of 4 kilocalorie (kcal) per g protein, 9 kcal per g fat and 4 kcal per g carbohydrate. These conversion factors were multiplied by 4.186 in order to obtain energy values in kilojoules (kJ) (WHO, 1985):

$$\text{Energy (kJ)} = (4\ \text{kcal/g} \times \text{g protein} \times 4.186) + (4\ \text{kcal/g} \times \text{g carbohydrate} \times 4.186) + (9\ \text{kcal/g} \times \text{g fat} \times 4.186)$$

2.3 MOISTURE DETERMINATION

Moisture analysis was carried out using the drying oven method (AOAC, 1990). Porcelain crucibles were weighed and their masses recorded. Five grams of each sample of the leaves were weighed into pre-weighed crucibles and dried in a drying oven at 105°C for 3 h. The crucibles containing samples were cooled in desiccators for 1 h and reweighed. The percentage moisture content was determined according to the formula:

$$\text{Percentage moisture} = \frac{\text{mass after 3 h (g)} - \text{initial mass (g)}}{\text{mass of sample (g)}} \times \frac{100}{1}$$

2.4 ASH DETERMINATION

Ash content was analysed according to the method of (AOAC, 1990). Dried porcelain crucibles were weighed and their masses recorded. Four grams of each plant sample were weighed into the crucibles. An aliquot of 7 ml glycerol/methanol (1:1 v/v) was added to the crucibles. The crucibles were ignited and burnt until all organic material volatilised. The crucibles were ashed by placing in a muffle furnace (Labcon, Laboratory Consumables and Chemical Supplies) at 600°C for 6 h. The crucibles were placed in desiccators and allowed to cool. The resulting crucibles were weighed and the percentage ash content was determined as follows:

$$\text{percentage ash} = \frac{\text{mass of ash (g)}}{\text{mass of sample (g)}} \times \frac{100}{1}$$

2.5 PROTEIN DETERMINATION

The Kjeldahl method (AOAC, 1990) was used for protein analysis using a Buchi 430 Digestor (Switzerland). This method is based on the assumption that a mixture of pure proteins will contain 16% nitrogen. The nitrogen concentration is determined by converting the nitrogen present in the sample to ammonium sulphate by digesting in concentrated sulphuric acid (H_2SO_4). The digested sample is then made alkaline with 32% sodium hydroxide (NaOH) (m/v). The ammonia is distilled into excess 2% boric acid solution and is determined by titration with standardised 0.1N H_2SO_4. The protein content is obtained by multiplying the percentage determined nitrogen by the appropriate factor, which is 6.25.

Three grams of sample, four grams of catalyst mixture (Appendix 1) and 25 ml of concentrated H_2SO_4 were weighed into clean dry digestion tubes (Buchi, Switzerland). The digestion tubes were connected to a NaOH trap for absorbing the noxious fumes and a vacuum was used to draw the fumes into the NaOH trap. The tubes containing the sample mixture were heated and the heating power was maintained such that samples

were always boiling. Digestion occurred for 45 min and was regarded as completed when the solution turned light green.

The digested samples were distilled by inserting the digestion tubes into the preheated Buchi 321 Distillation Unit (Switzerland) and were diluted with distilled water (1:3 v/v) followed by the addition of 100 ml of a 32% NaOH (w/v) solution. An aliquot of 25 ml of 2% boric acid and six drops of screened methyl red indicator was added to Erlenmeyer flasks that were placed under the distillation unit. Samples were distilled for 4 min. The distillate was titrated with 0.1N H_2SO_4 and the end point was reached when the light blue solution turned colourless to grey. The percentage nitrogen content was calculated as follows:

$$\text{Percentage N} = \frac{(\text{titration in ml} - \text{blank in ml}) \times 1.4 \times \text{normality of acid} \times 100}{\text{mass of sample} \times 10}$$

The percentage protein content was calculated as follows:

$$\text{Percentage protein} = 6.25 \times \%N$$

2.6 FAT DETERMINATION

The Soxhlet method was used to determine total fat (AOAC, 1990). This method is based on acid hydrolysis that liberates the bound fat. This is followed by solvent extraction of the fat. Acid hydrolysis was achieved by adding three grams of sample, 5g of celite 545 (Capital Lab Suppliers, New Germany) and 100 ml of 4N hydrochloric acid (HCl) to clean, dry digestion flasks (Buchi, Switzerland) and swirled to mix contents. Ten grams of sea sand (Merck, Germany) and 5 g of celite 545 were added into filter crucibles (Buchi, Switzerland). The raise/lower device of the Buchi hydrolysis unit B-425 (Switzerland) was placed in the top boil position and the filter crucibles were placed in the preheated digestion block. Sample aspiration tubes as well as the water jet pump for the vacuum extraction system was connected and samples were filtered into filter crucibles. Once filtration was complete, the heater was switched off. Empty

digestion tubes were rinsed out with aliquots of warm distilled water (50°C) into filter crucibles until no sample remained. Filter crucibles were dried in a drying oven at 80°C overnight.

The fat was extracted using a Buchi 810 Soxhlet system (Switzerland). The system was switched on, water tap opened and glass steam generator tap closed. Pre-dried beakers together with 2 boiling chips in each were weighed and their masses recorded. Beakers were filled with petroleum ether and inserted into the system. Filter crucibles containing samples were sealed with cotton wool and inserted into the extraction chamber. Beakers were constantly topped up with petroleum ether (40-60°C) using a plastic hypodermic sponge during the 6 h extraction period. At the end of the extraction period, the side lever was opened which allowed the solvent to drain out of the beakers. Heating continued until all the solvent evaporated from the beakers. Beakers with fat were placed in a drying oven overnight at 105°C, cooled in a desiccator and weighed. Results were analysed according to the formula:

$$\text{Percentage fat} = \frac{\text{mass of flask after drying - initial mass of flask} \times 100}{\text{mass of sample}}$$

2.7 FIBRE ANALYSIS

Dietary fibre was analysed by an enzymatic-gravimetric method using the Tecator Fibertec E System (Foss Tecator, Sweden), (AOAC, 1990).

2.7.1 Sample Preparation and Digestion

Samples were washed with distilled water and homogenised. High fat samples were defatted three times with 25 ml portions of petroleum ether/g of sample. Loss of weight was recorded due to fat removal and the appropriate correction to final percentage dietary fibre found in determination was made (AOAC, 1990).

Two blanks/assay were run with samples to measure any contribution from reagents to the residue. Duplicate 1 g samples (M_1 and M_2) were weighed accurately to 0.1 mg, into 400 ml tall-form beakers (Foss Tecator, Sweden). A volume of 40 ml N-morpholino-ethanosulphonic (MES)–tris-hydroxy-methyl-aminomethane (TRIS) buffer solution (Appendix 2), pH 8.2, was added to each. The beakers were stirred on magnetic stirrers until the samples were completely dispersed. An aliquot of 50 µl heat-stable ∝-amylase solution (Sigma, St Louis) was added and stirred at low speed. Beakers were covered with aluminium foil and incubated in a waterbath at 95-100°C for 15 min with continuous agitation. Timing commenced once bath temperature reached 95°C. The beakers were removed from the waterbath and cooled to 60°C. The aluminium foil was removed and the beaker walls and spatula were rinsed with 10 ml of water. An aliquot of 100 µl of protease solution (Sigma, St Louis) was added to each beaker, covered with aluminium foil and incubated at 60°C for 30 min. Timing commenced once the bath temperature reached 60°C. The foil was removed and a 5 ml aliquot of 0.561N HCl (Appendix 3) was dispensed into beakers while being stirred. A pH meter (Hanna Instruments, Lab Consumables and Chemical Supplies, Durban, South Africa) was used to adjust the pH to 4.0 – 4.7 at 60°C, by adding 1N NaOH solution or 1N HCl solution. An aliquot of 300 µl of amyloglucosidase solution (Sigma, St Louis) was added while stirring. The beakers were covered with aluminium foil and incubated for 30 min at 60°C with constant agitation. Timing commenced once bath temperature reached 60°C.

2.7.2 Dietary Fibre Determination

A volume of 225 ml of 95% ethanol at 60°C, measured after heating, was added to digested samples. The beakers were removed from the bath, covered with large sheets of aluminium foil and allowed to precipitate for 1 h at room temperature. Celite beds were redistrubuted in previously tared crucibles (Foss Tecator, Sweden) (Appendix 4) using 15 ml of 78% ethanol from wash bottle. Suction was applied to the crucibles to draw the celite 545 onto the fritted glass as even mat.

The alcohol-treated enzyme digestates were filtered through the crucibles. All remaining particles were quantitatively transferred to the crucibles using a wash bottle

containing 78% ethanol and a spatula. A vacuum was applied and the residue was washed two times each with 15 ml portions of 78% ethanol, 95% ethanol and acetone. The crucible containing the residue was dried overnight in a drying oven at 105°C and subsequently cooled in a desiccator for 1 h.

The crucible containing the dietary fibre residue and celite 545 was weighed to the nearest 0.1 mg and the residue weight was calculated by subtracting the weight of the dry crucible with celite 545. One duplicate from each sample was used to determine protein (Kjeldahl method). For ash analysis, the second duplicate was incinerated for 5 h at 525°C, cooled in desiccator and weighed to nearest 0.1 mg. Ash weight was determined by subtracting the weight of the crucible and celite 545.

Dietary fibre was calculated according to the following formulas:
Blank (B, mg) determination:

$$B = [(BR_1 + BR_2)/2] - P_B - A_B$$

where BR_1 and BR_2 = residue weights (mg) for duplicate blank determinations; and P_B and A_B = weights (mg) of protein and ash, respectively, determined on first and second blank residues.

Dietary fibre (DF, g/100 g) determination:

$$DF = \frac{\{[(R_1 + R_2)/2] - P - A - B\}}{[(M_1 + M_2)/2] \times 100}$$

where R_1 and R_2 = residue weights (mg) for duplicate samples; P and A = weights (mg) of protein and ash, respectively, determined on first and second residues; B = blank weight (mg); and M_1 and M_2 = weights (mg) for samples.

2.8 CARBOHYDRATE DETERMINATION

Carbohydrate content was determined using a difference method (FAO, 1985). The calculation is as follows:

Percentage carbohydrate = 100 – (protein + moisture + fat + ash)

2.9 VITAMIN A DETERMINATION

The method described by (Kimura and Rodriguez-Amaya, 2002) was used. Ten grams of each homogenised sample were weighed accurately into a boiling tube and mixed with 15 ml of potassium hydroxide in methanol (15% w/v). The alkaline mixture was saponified in a water bath at 75°C for 25 min. The contents were transferred to a separation funnel and vitamin A was extracted from the aqueous phase five times with 6 ml portions of fresh petroleum ether. The organic extracts were combined and then washed twice with 100 ml portions of distilled water until no more alkali was detected by pH paper. The resulting petroleum ether solution was filtered through a layer of anhydrous sodium sulphate. The extraction solvent was evaporated to dryness under vacuum in a rotary evaporator (Buchi R121 Rotavapor, Switzerland) and reconstituted in 1 ml of mobile phase consisting of methanol:water (90:10 v/v) to obtain test solutions.

Standard solutions of retinol consisting of 0.1, 0.2 and 0.4 mg/100 ml were prepared (Appendix 5) and test solutions (50 µl) were injected into the HPLC system (LaChrom, Merck, Germany). The mobile phase used was methanol:water (90:10 v/v) filtered through a 0.22 µm membrane. The flow rate was set to 1.5 ml/min. A liquid chromatograph with an ultraviolet detector set at 313 nm was used. The column was a C18 licrosphere RP18 (Merck, Germany). Retinol concentrations (µg/100g) were calculated in samples.

2.10 VITAMIN C DETERMINATION

Analysis of vitamin C was done according to the method of Vazquez Oderiz *et al* (1994). Ten grams of sample was mechanically stirred in 30 ml of a 4.5% (w/v) solution of metaphosphoric acid for 15 min. The mixture was filtered (Whatman No. 541) and the filtrate was diluted to 100 ml with double deionised water. An aliquot of the acid extract was then filtered through a 0.45 μm Millipore filter prior to injection into the chromatographic column. The mobile phase was double deionised water brought to pH 2.2 with metaphosphoric acid. The flow rate was 0.5 ml/min and the detection wavelength was set at 245 nm. The column used was a C18 licrosphere RP18 (Merck, Germany). Calibration curves based on analysis of standard solutions (Appendix 6) were constructed for Vitamin C analysis.

2.11 MINERAL ANALYSIS

Calcium, copper, iron, magnesium, manganese, zinc, sodium and phosphorus were analysed using the inductively coupled plasma (ICP) spectrometer (Perkin Elmer, Germany). Prior to analysis the dried sample extracts were digested in a microwave digester (Milestone Microwave Laboratory Systems, Italy).

2.11.1 Microwave Digestion

Three replicate aliquots (approximately 0.5 g) from each of the dried plant specimens were weighed into teflon vessels to which 3 ml concentrated nitric acid and 1 ml concentrated hydrogen peroxide were added. Each vessel was closed with its teflon cover and adapter and tightened with a spring disc. Vessels were positioned on the rotor and were secured by placing a circular safety band around them. The rotor was placed onto its base and each vessel was tightened using a torque wrench. The microwave oven and the fume extractor were switched on and the rotor was transferred to the microwave oven. The appropriate program from the instrument user manual was selected and the following parameters were entered:

	Step 1	Step 2	Step 3	Step 4	Step 5
W	250	0	250	400	600
Min	1	2	5	5	5

Once the operation was complete, the oven was switched off and the rotor was taken out of the oven. The vessels were allowed to cool and the contents were transferred into 50 ml volumetric flasks and made up to volume using double deionised water (Milestone Microwave Lab Systems, 1999).

2.11.2 Inductively Coupled Plasma Spectrometry

Working stock solutions of the mineral elements were prepared from the standard solutions (Appendix 7).

The ICP spectrometer was ignited and and the ICP 400 software program (Perkin Elmer, Germany) was loaded. The extractor fan, argon gas and the spectrometer were switched on. The peristaltic pump was turned on and deionised water was aspirated for 1 min. The torch was ignited and the nebulizer argon flow was set by performing the bullet test. This was achieved by aspirating a 1000 mg/ml solution of sodium. The plasma was examined through the viewing window of the torch compartment door and a yellow-orange bullet, extending from the base of the discharge to a point about 2-3 mm above the top of the RF coil, should be visible in the central channel of the discharge. A satisfactory bullet height was achieved by adjusting the nebulizer argon flow incrementally using the nebulizer adjustment knob. After setting the nebulizer argon flow, the system was allowed to stabilize for about one hour before developing methods or running samples.

A method was developed by entering the element parameters into the element mode and the samples, standards and blanks were aspirated and read. The calibrated wavelengths as well as the element parameters were stored in the element mode whilst the element parameters and element file names were entered and stored in the method mode. The method file name was accessed and the standards, blank and samples were aspirated and

read. A quality control standard of known concentration of each element analysed was determined after every five samples in order to verify accuracy of the procedure. Upon completion of analysis, deionised water was aspirated for five minutes, the plasma was shut down and the software program was exited.

The concentrations of minerals were calculated using the concentration from the ICP analysis reports. The formula used is as follows:

$$\text{Concentration (mg 100 g}^{-1}\text{)} = \frac{\text{Instrument concentration (ppm)} \times \text{volume (ml)} \times 100}{\text{Mass of sample (g)}}$$

Sample solutions were quantified against standard solutions of known concentration that were analysed concurrently (Perkin Elmer, 1996).

CHAPTER THREE: RESULTS

3.1 LEAFY VEGETABLE DESCRIPTION AND TRADITIONAL USAGE

The twenty leafy vegetables used in this study were collected from the greater Durban area in Kwa-Zulu Natal, South Africa during 2001 and 2002. These leafy vegetables were identified using available taxonomic keys into thirteen families, namely, Solanaceae, Cucurbitaceae, Amaranthaceae, Acanthaceae, Polygonaceae, Asteraceae, Capparaceae, Portulacaceae, Campanulaceae, Fabaceae, Chenopodiaceae, Pedaliaceae and Apiaceae. The food, medicinal, nutritional and toxicity characteristics of the traditional leafy vegetables are presented in Table 3.1.

Table 3.1 Summary of characteristics of traditional leafy vegetables studied

Scientific Name	Family	English Name	Edible Uses	Nutritional Value Abundant in:	Medicinal Uses	Toxicity
Solanum nigrum	Solanaceae	Black nightshade	Leaves used as potherb, relish. Ripe fruit is eaten (Fox and Norwood Young, 1982).	**Fibre, carbohydrates, Ca, P, Na, Cu, Zn, Mg**	Antiphlogistic, diaphoretic, diuretic, emollient, antiperiodic, febrifuge, narcotic, purgative, sedative (Duke and Ayensu, 1985), Used as poultice in treatment of cancerous sores, leucoderma, wounds (Moerman, 1998).	Toxicity is variable. Green berries contain solanine causing degrees of poisoning (Tredgold, 1986).

Table 3.1 Summary of characteristics of traditional leafy vegetables studied (cont.)

Scientific Name	Family	English Name	Edible Uses	Nutritional Value Abundant in:	Medicinal Uses	Toxicity
Physalis viscosa	Solanaceae	Grape ground-cherry	Fruit and berries are edible (Felter and Lloyd – cited by King's American Dispensatory, 1992).	**High protein, Carbohydrates, Ca, P, Na, Cu, Zn, Mg**	The plant is used as a tonic, laxative, diuretic and sedative. The juice of the berries is beneficial in several urinary disorders. Used to treat inflammatory diseases.	No toxicity reports available.
Cucumis metuliferus	Cucurbitaceae	Horned cucumber	Cooked as spinach, side dish. Fruit eaten raw in times of famine (Fox and Norwood Young, 1982).	**Fibre, Ca, P, Na, Cu, Zn, Mg**	Seeds are vermifuge. Decoction of roots relieves pain following childbirth (Tredgold, 1984).	Cucurbitacines present in fruit results in bitterness and are purgative and emetic harmful to humans and animals (Benzioni, 1998).
Momordica balsamina	Cucurbitaceae	Balsam apple	Cooked as spinach, with nuts or mielie meal, relish, soup (Fox and Norwood Young, 1982).	**Protein. Fibre, Ca, P, Na, Cu, Zn, Mg**	Leaves used for liver deficiencies, blood cleanser, ulcers of the stomach and duodenum, inflammations, insomnia, marsh fever, urinary tract infections, bile disorders. Used as a purgative, emetic, bitter stomachic and as a wash for fever and yaws Dalziel, 1937 – cited by Burkhill, 1985)	No toxicity reports available.

Table 3.1 Summary of characteristics of traditional leafy vegetables studied (cont.)

Scientific name	Family	English Name	Edible Uses	Nutritional Value Abundant in:	Medicinal Uses	Toxicity
Amaranthus spinosus	Amaranthaceae	Spiny pigweed	Eaten raw or cooked as spinach (Kunkel, 1984). Famine food (Fox and Norwood Young, 1982).	**Protein, fibre, Ca, P, Na, Cu, Zn, Mg**	Astringent, diaphoretic, diuretic, emollient, febrifuge, purgative. Used to treat snake bites, ulcerated mouths, vaginal discharges, nosebleeds, wounds (Bown, 1995).	No members of this genus are known to be poisonous (Plants for a Future, 1997-2000).
Amaranthus hybridus	Amaranthaceae	Cockscomb	Relish, mixed with mielie meal (Fox and Norwood Young, 1982). Cooked as spinach, added to soups, eaten raw (Facciola, 1990)	**Protein, Ca, P, Na, Cu, Zn, Mg**	Tea made from leaves is astringent (Foster and Duke, 2000). Used in treatment of intestinal bleeding, diarrhoea, excessive menstruation (Moerman, 1998).	No members of this genus are known to be poisonous (Plants for a Future, 1997-2000).
Amaranthus dubius	Amaranthaceae		Potherb, cooked and eaten as spinach. Seeds are nutritious (Burkhill, 1985).	**Ca, P Na, Cu, Zn, Mg**	The whole plant is used to alleviate stomach pains (Burkhill, 1985).	No members of this genus are known to be poisonous (Plants for a Future, 1997-2000).
Asystasia gangetica	Acanthaceae	Hunter's spinach	Leaves are edible occasionally (Burkhill, 1985).	**Carbohydrates, Ca, P, Na, Cu, Zn, Mg**	To ease childbirth pains, facilitate labour, stomach aches, fever aches, epilepsy, heart pains (Bouquet, 1969 – cited by Burkhill, 1985).	No toxicity reports available.

Table 3.1 Summary of characteristics of traditional leafy vegetables studied (cont.)

Scientific name	Family	English Name	Edible Uses	Nutritional Value Abundant in:	Medicinal Uses	Toxicity
Justicia flava	Acanthaceae	Yellow justicia	Semi cultivated and eaten as a vegetable (Busson, 1965 – cited by (Burkhill, 1985).	**Carbohydrates, Ca, P, Na, Cu, Zn, Mg**	Stomach ache, diarrhoea, (Kokwaro, 1976 – cited by Albert and Foster, 1996). Treats fevers and yaws. Leaves used as emetics and eye lotions (Iwu, 1993 – cited by Leung and Foster, 1996).	No toxicity reports available.
Emex australis	Polygonaceae	Devil's thorn	Cooked as spinach (Fox and Norwood Young, 1982).	**Ca, P, Na, Cu, Zn, Mg**	Used to treat gastrointestinal disorders, colic, biliousness and dyspepsia (Hutchings *et al.*, 1996).	Contains oxalic acid (Fuller, 1998).
Oxygonum sinuatum	Polygonaceae			**Ca, P, Na, Cu, Zn, Mg**	Leaf sap used for cough and bronchial catarrh (Bally 1937 – cited by Neuwinger, 2000). Used foe gastric ulcers, malaria and hepatitis (Rwangabo, 1993 – cited by Neuwinger, 2000).	No toxicity reports available.

Table 3.1 Summary of traditional leafy vegetables studied (cont.)

Scientific name	Family	English name	Edible uses	Nutritional Value Abundant in:	Medicinal Uses	Toxicity
Bidens pilosa	Asteraceae	Blackjack	Potherb, tea, salads, soups, stews (Facciola, 1990). Relish, peanut butter added (Tredgold, 1986).	**Protein, Ca, P Na, Cu, Zn, Mg**	Leaves are anti-inflammatory and styptic. Substances isolated are bactericidal, fungicidal. A juice made from leaves used to dress wounds (Duke and Ayensu, 1985).	Substances isolated from leaves can destroy human skin in sunlight at concentrations of 10 ppm (Duke andAyensu,1985).
Galinsoga parviflora	Asteraceae	Gallant soldier	Eaten as a potherb, raw or cooked. Flavouring in soups, used as a (Facciola, 1990).	**Ca, Na, Cu, Zn, Mg**	When rubbed onto the body, the plant is useful in treating nettle stings (Chopra *et al.*, 1986).	No toxicity reports available
Cleome monophylla	Capparaceae	Spindle-pod	Potherb. Leaves cooked with groundnuts, cowpeas or tomatoes (Fox and Norwood Young, 1982).	**Protein, fibre, Ca, P Na, Cu, Zn, Mg**	Leaves applied to sores, roots chewed for coughs and the whole plant is used externally for swellings. Used as an anthelmintic (Dokosi, 1998).	No toxicity reports available.
Portulaca oleracea	Portulacaceae	Purslane	Eaten as salad and vegetable (Leung and Foster, 1996) Can be eaten raw (Van Wyk and Gericke, 2000).	**Ca, P, Na, Cu, Zn, Mg**	Whole plant to be bactericidal in bacillary dysentry, diarrhoea, haemorrhoids and enterorrhagia. (Boulos, 1993), antibacterial, antiscorbutic, depurative, diuretic, febrifuge (Bown, 1995).	9% oxalic acid. Incoordination of gait and tetanic conditions in sheep (Webb, 1948 – cited by Burkhill, 1997).

Table 3.1 Summary of traditional leafy vegetables studied (cont.)

Scientific name	Family	English Name	Edible Uses	Nutritional Value Abundant in:	Medicinal Uses	Toxicity
Wahlenbergia undulata	Campanulaceae	Giant bell flower	Leaves cooked as spinach (Tredgold, 1986).	**Carbohydrates, Protein, Ca, P, Na, Cu, Zn, Mg**	Used to treat internal ulcers in children and ophthalmia (Hutchings *et al.*, 1996).	No toxicity reports available.
Senna occidentalis	Fabaceae	Cassia senna	Young leaves are eaten (Bittenbender *et al.*, 1984). Regarded as a famine food (Becker, 1983). Roasted seed is used as coffee substitute (Fox and Norwood Young, 1982).	**Protein. Fat, fibre, Ca, P, Na, Cu, Zn, Mg**	Used for stomach pains, biliousness, fevers, jaundice, ringworms, sore throats and wounds (Taylor, 2002). Dried leaves are used for lumbago and haemorrhoids whilst fresh leaves are used to treat edemas, abscesses and skin diseases (Hirt, 1992 – cited by Neuwinger, 2000).	Unroasted seeds are toxic (Fox and Norwood Young, 1982). Leaves are toxic only if large quantities are consumed (Russell *et al.*, 1997).
Chenopodium album	Chenopodiaceae	Fat hen	Cooked as spinach, mielie meal added, eaten as porridge, relish Seeds dried, ground into a meal and used as gruel, eaten raw, added to salads (Facciola, 1990).	**Protein, carbohydrates, Ca, P, Na, Cu, Zn, Mg**	Leaves are anthelmintic, antiphlogistic, anti-rheumatic, mildly laxative, odontalgic (Foster and Duke, 1990). Applied as a wash or poultice to bug bites, sunstroke, rheumatic joints, swollen feet (Duke and Ayensu, 1985).	Contains small amounts of saponins. Cooking the plant reduces the oxalic acid content (Bown, 1995). Raw leaves eaten in large quantities causes problems (Schoefield *et al.*, 1990).

Table 3.1 Summary of traditional leafy vegetables studied (cont.)

Scientific name	Family	English Name	Edible Uses	Nutritional Value Abundant in:	Medicinal Uses	Toxicity
Ceratotheca triloba	Pedaliaceae	Wild foxglove	Cooked as spinach. Unpleasant scent disappears with boiling. Sweet tasting and used a relish (Tredgold, 1986).	**Fat, fibre, carbohydrates, Ca, P Na, Cu, Zn, Mg**	Used in treatment of painful menstruation, stomach cramps, nausea, fever and diarrhoea (Watt and Breyer Brandwijk – cited by Hutchings *et al.*, 1996). To relieve gastric disorders (Tredgold, 1986).	No toxicity reports available.
Centella asiatica	Apiaceae	Marsh pepperwort	Eaten as spinach, mixed with mielie meal. Leaves are dried and used as famine food (Fox and Norwood Young, 1982). Used in salads and curries (Bown, 1995).	**Fat, Ca, P, Na, Cu, Zn, Mg**	Rejuvenating diuretic herb that clears toxins, reduces inflammations and fevers, improves healing and immunity, improves the memory and has a balancing effect on the nervous system Used in treatment of wounds, chronic skin conditions, venereal diseases, malaria, varicose veins, ulcers, nervous disorders and senility (Bown, 1995; Chopra *et al.*, 1986).	In large doses, this plant is a stupefying narcotic, sometimes producing cephalagia or vertigo with a tendency to coma (Chopra *et al.*, 1949 – cited by (Dokosi, 1998).

3.2 ENERGY AND PROXIMATE COMPOSITION OF SAMPLE AND PUBLISHED VALUES

A database of published results of the nutritional value of indigenous plants was consulted (Table 3.2) and used as a guideline to in the present study. Table 3.2 presents the database by Maundu *et al.* (1999) of published results of the nutritional value of indigenous edible plants consumed in Africa per 100 g fresh weight.

From the twenty traditional leafy vegetables analysed in this study, the nutritional values of six vegetables namely, *Solanum nigrum*, *Amaranthus spinosus*, *Amaranthus hybridus*, *Amaranthus dubius*, *Asystasia gangetica* and *Portulaca oleracea* were found in previously published literature (Table 3.2).

The raw data of the nutritional value of the traditional leafy vegetables (Appendix 8) was used to determine the mean values for energy and proximate composition of the twenty vegetables analysed in this study and are presented in Table 3.3.

Vegetables contain generally 90-96% water and very low levels of fat, below 0.5%. However, significant quantities of fat are found in certain leafy plants. Carbohydrates are the main component of vegetables and represent more than 90% of their dry matter. The chemical composition determines the nutritive value of the crops and the technological value of the raw material. Within a given species these values depend on the biological factors, such as the cultivar and on the agrotechnical conditions (Kmiecik *et al.*, 2002).

Table 3.2 Database of nutritional information of indigenous plants per 100 g from previously published literature (Maundu, *et al.*, 1999).

Plants	Family	Plant Part	Energy (kJ)	Water (%)	Protein (g)	Fibre (g)	Ash (g)	Fat (g)	Na (mg)	P (mg)	Ca (mg)	Mg (mg)	Fe (mg)
Adansonia digitata	Bombacaceae	leaves	289	77	3.8	2.8	-	-	-	-	400	-	-
Aerva lanata	Amaranthaceae	leaves	-	85.85	2.59	-	3.46	-	-	-		-	-
Aerva lanata	Amaranthaceae	leaves	201	83.1	3.9	2.1	3	0.6	-	86	493	-	-
Amaranthus sp.	Amaranthaceae	leaves	-	83.28	3.15	2.01	3.12	0.21	-	-	-	-	-
Amaranthus sp.	Amaranthaceae	leaves	176	84	4.6	-	-	0.2	-	103	410	-	-
Amaranthus spinosus	**Amaranthaceae**	**leaves**	**151**	**86.9**	**3.5**	**1.3**	**2.6**	**0.5**	**-**	**67**	**267**	**-**	**3.9**
Amaranthus caudatus	Amaranthaceae	leaves	-	75.51	4.72	3.02	5.55	0.29	-	-	-	-	-
Amaranthus cruentus	Amaranthaceae	leaves	-	79.96	4.84	2	4.36	-	2.2	94.18	673	644	10.62
Amaranthus dubius	**Amaranthaceae**	**leaves**	**-**	**80.74**	**3.83**	**3.33**	**3.45**	**0.2**	**-**	**-**	**-**	**-**	**-**
Amaranthus hybridus	**Amaranthaceae**	**leaves**	**336**	**72.7**	**6.3**	**2.8**	**5.2**	**0.5**	**6.54**	**116**	**553**	**329**	**10.9**
Amaranthus thunbergii	Amaranthaceae	leaves	147	83.6	4.3	2.8	5.1	0.2	14.4	67.5	313	135	13.6
Asystasia gangetica	**Acanthaceae**	**leaves**	**-**	**88.04**	**2.96**	**1.3**	**2.95**	**-**	**38.41**	**43.08**	**379**	**242**	**15.56**
Basella alba	Basellaceae	leaves	-	90.2	1.85	1.5	1.4	0.33	-	-	-	-	-
Basella alba	Basellaceae	leaves	84	92.5	1.8	0.8	1.7	0.3	-	69	138	-	-
Basella alba	Basellaceae	leaves	80	93.4	1.6	0.6	-	-	-	-	105	1.6	-
Brassica carinata	Brassicaceae	leaves	-	86.1	3.5	1.6	3.4	0.8	-	77	-	-	-
Cleome gynandra	Capparaceae	leaves	181	85	5.1	1.3	3.6	0.6	33.6	12.0	262	86.8	18.8
Cleome gynandra	Capparaceae	leaves	142	86.6	4.8	1.2	3.0	0.4	-	111	288	-	6.0

Table 3.2 Database of nutritional information of indigenous plants per 100 g from previously published literature (cont.) (Maundu, *et al.*, 1999).

Plants	Family	Plant Part	Energy (kJ)	Water (%)	Protein (g)	Fibre (g)	Ash (g)	Fat (g)	Na (mg)	P (mg)	Ca (mg)	Mg (mg)	Fe (mg)
Commelina benghalensis	Commelinaceae	leaves	-	82.31	3.79	-	1.98		2.83	37.15	228	109	11.59
Corchorus olitorius	Tiliaceae	leaves	243	80.4	4.5	2.0	2.4	0.3	-	122	360	-	7.2
Corchorus olitorius	Tiliaceae	leaves	180	86.1	5.6	1.7	-	-	-	-	270	-	7.7
Corchorus trilocularis	Tiliaceae	leaves	-	86.91	3.36	1.43	1.83	-	-	-	-	-	-
Crotalaria brevidens	Fabaceae	leaves	-	74.5	8.8	1.6	1.6	-	-	-	222	-	0.8
Crotalaria brevidens	Fabaceae	leaves	-	-	4.55	-		-	-	-	270	-	38
Crotalaria ochroleuca	Fabaceae	leaves	-	74.5	8.8	-	1.6	-	-	-	-	-	-
Cucumis dispaceus	Cucurbitaceae	leaves	146	89.9	1	-	0.8	0.7	-	25	14	-	1
Digera muricata var. patentipilosa	Amaranthaceae	leaves	-	88.48	3.2	1.07	2.53	-	65.32	73.73	316	190.4	14.9
Digera muricata ssp. trinervis	Amaranthaceae	leaves	-	88.43	2.89	1.97	2.44	0.04	-	-	-	-	-
Hyphaene coriacea	Arecaceae	leaves	-	87.95	3.15	1.13	1.3	-	-	-	-	-	-
Ipomoea aquatica	Convolvulaceae	leaves	-	83.54	3.42	2.25	1.81	-	-	-	-	-	-
Ipomoea aquatica	Convolvulaceae	leaves	184	85.0	3.3	1.9	2.0	0.4	121.74	61.85	261.5	73.3	11.7
Ipomoea longituba	Convolvulaceae	leaves	-	87.3	3.25	1.9	2.16	0.26	6.32	22.85	599	72.61	6
Ipomoea mombassana	Convolvulaceae	leaves	-	86	-	2.1	1.89	0.29	-	-	-	-	-
Ipomoea mombassana	Convolvulaceae	leaves		88	3.0	2.58	2.45	0.2					

Table 3.2 Database of nutritional information of indigenous plants per 100 g from previously published literature (cont.). (Maundu, *et al.*, 1999).

Plants	Family	Plant Part	Energy (kJ)	Water (%)	Protein (g)	Fibre (g)	Ash (g)	Fat (g)	Na (mg)	P (mg)	Ca (mg)	Mg (mg)	Fe (mg)
Kedrostis pseudogijef	Cucurbitaceae	leaves		88	3.0	2.58	2.45	0.2					
Launaea cornuta	Asteraceae	leaves		88.77	2.66	1.29	2.16						
Launaea cornuta	Asteraceae	leaves		82.69	3.62	1.98	2.61		1.62	48.47	355.2	121.69	12.72
Leptadenia hastata	Asclepiadaceae	leaves	226	81.0	4.9	4.7	2.6	0.2		94	417		5.4
Ocimum basilicum	Lamiaceae	leaves	313	77.1	5.5	2.1	5.2	1.4					
Oxygonum salicifolium	Polygonaceae	leaves		88.69	2.3	1.68	2.1						
Portulaca oleracea	**Portulacaceae**	**leaves**	**96**	**90.6**	**2.4**	**0.8**	**2.5**	**0.3**		**31**	**104**		**1.4**
Portulaca oleracea	**Portulacaceae**	**leaves**	**142**	**87.5**	**2.2**	**1.1**					**115**		**1.4**
Sesamum calycinum	Pedaliaceae	leaves		76.51	5.6	2.23	2.23	0.62	2.32	59.95	373.5	168.9	35.22
Solanum nigrum	**Solanaceae**	**leaves**	**159**	**87.2**	**4.3**	**1.3**	**2**	**0.8**		**75**	**442**		**1.0**
Solanum nigrum	**Solanaceae**	**leaves**	**184**	**85**	**4.6**	**1.1**					**215**		**4.2**
Urtica massaica	Urticaceae	leaves		80.45	5.79	1.82	3.26						
Vatovaea pseudolablab	Fabaceae	leaves		83.44	5.41	2.89	1.69	0.66					
Vernonia cinerea	Asteraceae	leaves		89.32	2.8	1.16	2.41						
Vigna membranacea	Fabaceae	leaves		80.9	6.56	2.0	2.83	0.37			110		4.7
Vigna unguiculata	Fabaceae	leaves	142	88.4	4.2	1.7							
Vigna unguiculata	Fabaceae	leaves		84.4	4.7	1.8	2	0.3					
Vigna unguiculata	Fabaceae	leaves	184	85	4.7			0.3		63	256		

Table 3.3 Nutritional value of traditional leafy vegetables studied (per 100 g fresh weight ± SD)

Plants	Energy (kJ)	Moisture (%)	Protein (g)	Fat (g)	Fibre (g)	Ash (g)	Carbohydrates (g)
Solanum nigrum	229.31 ± 4.86	84.84 ± 0.17	3.27 ± 0.21	0.62 ± 0.03	2.42 ± 0.03	2.24 ± 0.16	9.03 ± 0.57
Physalis viscosa	289.63 ± 6.86	81.49 ± 0.3	5.62 ± 0.06	0.83 ± 0.06	1.97 ± 0.07	2.25 ± 0.18	9.81 ± 0.59
Cucumis metuliferus	179.37 ± 2.06	87.47 ± 0.16	3.52 ± 0.03	0.73 ± 0.07	2.42 ± 0.07	2.73 ± 0.06	5.55 ± 0.31
Momordica balsamina	222.15 ± 4.09	85.28 ± 0.29	5.34 ± 0.31	0.49 ± 0.04	2.75 ± 0.04	2.07 ± 0.1	6.82 ± 0.16
Amaranthus spinosus	111.02 ± 1.12	91.36 ± 0.25	4.12 ± 0.06	0.60 ± 0.01	2.48 ± 0.08	2.76 ± 0.34	1.16 ± 0.16
Amaranthus hybridus	221.07 ± 1.29	82.55 ± 0.07	5.92 ± 0.04	0.53 ± 0.08	2.81 ± 0.03	4.91 ± 0.11	6.09 ± 0.31
Amaranthus dubius	205.79 ± 5.68	84.59 ± 0.38	3.89 ± 0.08	0.24 ± 0.06	2.87 ± 0.04	3.42 ± 0.03	7.86 ± 0.55
Asystasia gangetica	207.63 ± 4.03	85.36 ± 0.35	3.05 ± 0.06	0.48 ± 0.06	1.63 ± 0.04	2.84 ± 0.04	8.27 ± 0.31
Justicia flava	215.52 ± 1.78	84.31 ± 0.1	3.20 ± 0.03	0.40 ± 0.03	1.39 ± 0.01	3.32 ± 0.04	8.77 ± 0.2
Emex australis	148.61 ± 4.97	89.18 ± 0.21	4.93 ± 0.0	0.54 ± 0.06	1.57 ± 0.07	2.62 ± 0.01	2.73 ± 0.17
Oxygonum sinuatum	108.63 ± 7.40	91.94 ± 0.66	2.58 ± 0.16	0.47 ± 0.1	1.68 ± 0.01	2.16 ± 0.1	2.85 ± 0.51
Bidens pilosa	163.85 ± 1.18	88.12 ± 0.1	4.76 ± 0.08	0.58 ± 0.06	2.92 ± 0.13	2.82 ± 0.04	3.72 ± 0.28
Cleome monophylla	162.80 ± 7.22	88.08 ± 0.35	4.86 ± 0.1	0.65 ± 0.08	2.14 ± 0.03	3.01 ± 0.03	3.40 ± 0.14
Portulaca oleracea	99.38 ± 1.96	92.63 ± 0.13	2.52 ± 0.01	0.34 ± 0.04	1.21 ± 0.04	1.86 ± 0.04	2.65 ± 0.23
Wahlenbergia undulata	313.28 ± 11.25	79.64 ± 0.74	5.23 ± 0.06	0.32 ± 0.03	1.33 ± 0.04	2.05 ± 0.1	12.76± 0.55
Senna occidentalis	353.93 ± 4.14	77.40 ± 0.19	6.79 ± 0.07	2.21 ± 0.06	2.58 ± 0.03	4.23 ± 0.13	9.37 ± 0.45
Chenopodium album	245.31 ± 1.07	83.36 ± 0.06	4.60 ± 0.03	0.76 ± 0.03	1.92 ± 0.06	2.94 ± 0.04	8.34 ± 0.16
Ceratotheca triloba	258.74 ± 4.36	84.99 ± 0.27	2.29 ± 0.11	2.17 ± 0.07	2.07 ± 0.06	2.27 ± 0.07	8.28 ± 0.52
Galinsoga parviflora	170.58 ± 7.88	88.71 ± 0.4	3.75 ± 0.04	0.51 ± 0.04	1.24 ± 0.08	1.74 ± 0.13	5.29 ± 0.61
Centella asiatica	219.01 ± 0.54	87.78 ± 0.03	3.15 ± 0.24	2.72 ± 0.04	1.92 ± 0.04	2.54 ± 0.06	3.81 ± 0.37

3.2.1 Energy Content

Senna occidentalis and *Wahlenbergia undulata* yielded the highest energy levels of 353.93 kJ 100 g^{-1} and 313.28 kJ 100 g^{-1}, respectively. The results indicate that fifty percent of the leafy vegetables have very high yielding energy values ranging from 300 kJ 100 g^{-1} to 200 kJ 100 g^{-1}, namely, *Physalis viscosa* (289.63 kJ 100 g^{-1}), *Ceratotheca triloba* (258.74 kJ 100 g^{-1}), *Chenopodium album* (245.31 kJ 100 g^{-1}), *Solanum nigrum* (229.31 kJ 100 g^{-1}), *Momordica balsamina* (222.15 kJ 100 g^{-1}), *Amaranthus hybridus* (221.07 kJ 100 g^{-1}), *Centella asiatica* (219.01 kJ 100 g^{-1}), *Justicia flava* (215.50 kJ 100 g^{-1}), *Asystasia gangetica* (207.63 kJ 100 g^{-1}), and *Amaranthus dubius* (205.79 kJ 100 g^{-1}). The remaining vegetable species are also good sources of energy. *Portulaca oleracea* contained the lowest energy value of 99.38 kJ 100 g^{-1}.

Fig. 3.21 represents the energy content obtained from this study and published values of the six leafy vegetables. The sample value of *Solanum nigrum* yielded a higher energy content of 229.31 kJ 100 g^{-1} than the published value of 159 kJ 100 g^{-1}.

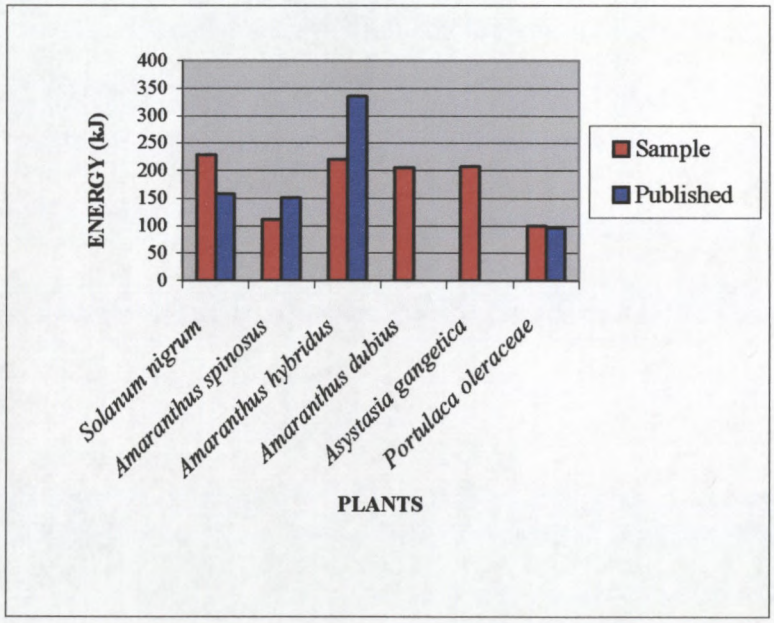

Fig. 3.1 Energy content of sample and published values (Maundu *et al.*, 1999) of six leafy vegetables per 100 g

Both values for *Portulaca oleracea* provide roughly equivalent amounts of energy; sample value (99.38 kJ 100 g^{-1}) and published value (96.00 kJ 100 g^{-1}). The sample value of *Amaranthus hybridus* (221.07 kJ 100 g^{-1}) was lower than the published value (336 kJ 100 g^{-1}). No data on the energy content of *Amaranthus dubius* and *Asystasia gangetica* from the database in Table 3.2 has been reported.

3.2.2 Moisture Content

The moisture content of all the leafy vegetables analysed was high. All leafy vegetables samples contained between 75% and 95% moisture. *Portulaca oleracea* contained the highest moisture content of 92.63% followed by *Oxygonum sinuatum* (91.94%) and *Amaranthus spinosus* (91.36%). The lowest moisture content was recorded for the leaves of *Senna occidentalis* (77.40%).

The moisture content of the six leafy vegetables in this study was very similar as shown graphically in Fig 3.22.

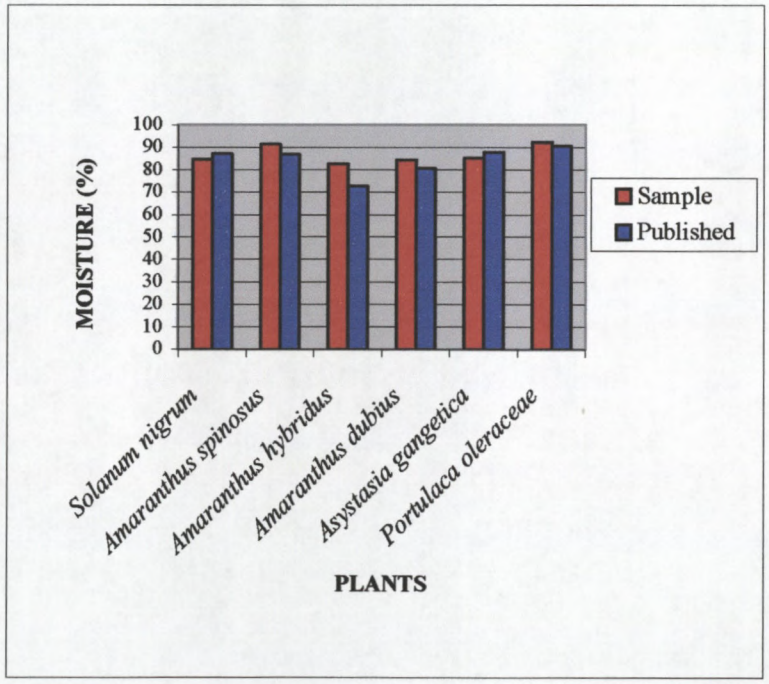

Fig. 3.2 Moisture content of sample and published values (Maundu *et al.*, 1999) of six leafy vegetables per 100 g

The sample values of four of the leafy vegetables namely *Amaranthus spinosus*, *Amaranthus hybridus*, *Amaranthus dubius* and *Portulaca oleracea* contained higher moisture levels than the published results. The moisture content of the published values for *Solanum nigrum* (87.2%) and *Asystasia gangetica* (88.04%) was approximately 3% higher than the sample values.

3.2.3 Protein Content

The RDA of protein is 50 g per day for adults (Food and Nutrition Board, 1989). *Senna occidentalis* provided the most abundant source of protein (6.79 g 100 g^{-1}), followed by *Amaranthus hybridus* (5.92 g 100 g^{-1}), *Physalis viscosa* (5.62 g 100 g^{-1}), *Momordica balsamina* (5.34 g 100 g^{-1}) and *Wahlenbergia undulata* (5.23 g 100 g^{-1}). The relatively high values for *Emex australis* (4.93 g 100 g^{-1}), *Cleome monophylla* (4.86 g 100 g^{-1}), *Bidens pilosa* (4.76 g 100 g^{-1}), *Chenopodium album* (4.60 g 100 g^{-1}) and *Amaranthus spinosus* (4.12 g 100 g^{-1}) were noteworthy.

Substantial amounts of protein were found in the leaves of *Amaranthus dubius* (3.89 g 100 g^{-1}), *Galinsoga parviflora* (3.75 g 100 g^{-1}), *Cucumis metuliferus* (3.52 g 100 g^{-1}), *Solanum nigrum* (3.27 g 100 g^{-1}), *Justicia flava* (3.20 g 100 g^{-1}), *Centella asiatica* (3.15 g 100 g^{-1}) and *Asystasia gangetica* (3.05 g 100 g^{-1}). Low protein contents were reported for samples of *Oxygonum sinuatum* (2.58 g 100 g^{-1}), *Portulaca oleracea* (2.52 g 100 g^{-1}) and *Ceratotheca triloba* (2.29 g 100 g^{-1}).

The results found in our study and published values of the six leafy vegetables are presented in Fig. 3.23. Results from this study for the protein content indicated that *Amaranthus spinosus* (4.12 g 100 g^{-1}), *Amaranthus dubius*, *Asystasia gangetica* (3.05 g 100 g^{-1}) and *Portulaca oleracea* (2.52 g 100 g^{-1}) were slightly higher than the published values of *Amaranthus spinosus* (2.86 g 100 g^{-1}), *Amaranthus dubius*, *Asystasia gangetica* (3.89 g 100 g^{-1}) and *Portulaca oleracea* (2.4 g 100 g^{-1}). The protein content of results obtained in this study for *Solanum nigrum* (3.27 g 100 g^{-1}) and *Amaranthus hybridus* (5.92 g 100 g^{-1}) were lower than the published values of *Solanum nigrum* (4.3 g 100 g^{-1}) and *Amaranthus hybridus* (6.3 g 100 g^{-1}).

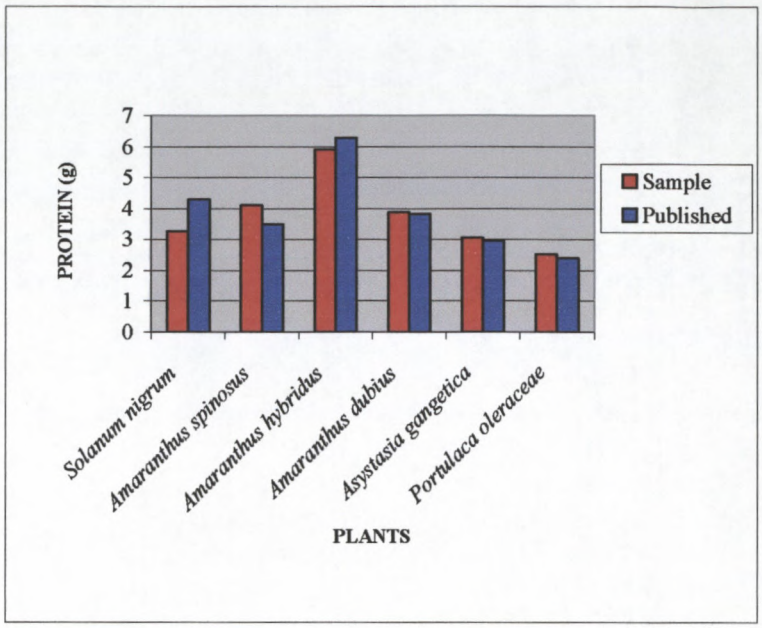

Fig. 3.3 Protein content of sample and published values (Maundu *et al.*, 1999) of six leafy vegetables per 100 g

3.2.3 Fat Content

Three samples namely *Centella asiatica* (2.72 g 100 g^{-1}), *Senna occidentalis* (2.21 g 100 g^{-1}) and *Ceratotheca triloba* (2.17 g 100 g^{-1}) stand out as being very good sources of fat. The fat content of all remaining leafy vegetables specimens ranged from a low of 0.24 g 100 g^{-1} (*Amaranthus dubius*) to 0.83 g 100 g^{-1} (*Physalis viscosa*). The leaves of *Physalis viscosa* (0.83 g 100 g^{-1}), *Chenopodium album* (0.76 g 100 g^{-1}), *Cucumis metuliferus* (0.73 g 100 g^{-1}) contained considerable amounts of fat. There was an approximate difference of 0.01 g 100 g^{-1} in the leaves of *Cleome monophylla* (0.65 g 100 g^{-1}), *Solanum nigrum* (0.62 g 100 g^{-1}), *Amaranthus spinosus* (0.60 g 100 g^{-1}), *Bidens pilosa* (0.58 g 100 g^{-1}), *Emex australis* (0.54 g 100 g^{-1}), *Amaranthus hybridus* (0.53 g 100 g^{-1}), *Galinsoga parviflora* (0.51 g 100 g^{-1}), *Momordica balsamina* (0.49 g 100 g^{-1}), *Asystasia gangetica* (0.48 g 100 g^{-1}) and *Oxygonum sinuatum* (0.47 g 100 g^{-1}). The lowest fat values were found in the leaves of *Justicia flava, Portulaca oleracea, Wahlenbergia*

undulata and *Amaranthus dubius* having values of 0.40 g 100 g^{-1}, 0.34 g 100 g^{-1}, 0.32 g 100 g^{-1} and 0.24 g 100 g^{-1}, respectively.

Fig 3.24 represents the fat content of the six published and sample values of the leafy vegetables. Four of the leafy vegetables analysed in this study contained higher fat levels than published results. These leafy vegetables are *Amaranthus spinosus*, *Amaranthus dubius*, *Amaranthus hybridus* and *Portulaca oleracea* having sample and published values of (0.6 g 100 g^{-1} and 0.50 g 100 g^{-1}), (0.53 g 100 g^{-1} and 0.5 g 100 g^{-1}), (0.24 g 100 g^{-1} and 0.20 g 100 g^{-1}) and (0.34 g 100 g^{-1} and 0.30 g 100 g^{-1}), respectively. The published value of *Solanum nigrum* (0.80 g 100 g^{-1}) was higher than the sample value of 0.62 g 100 g^{-1}.

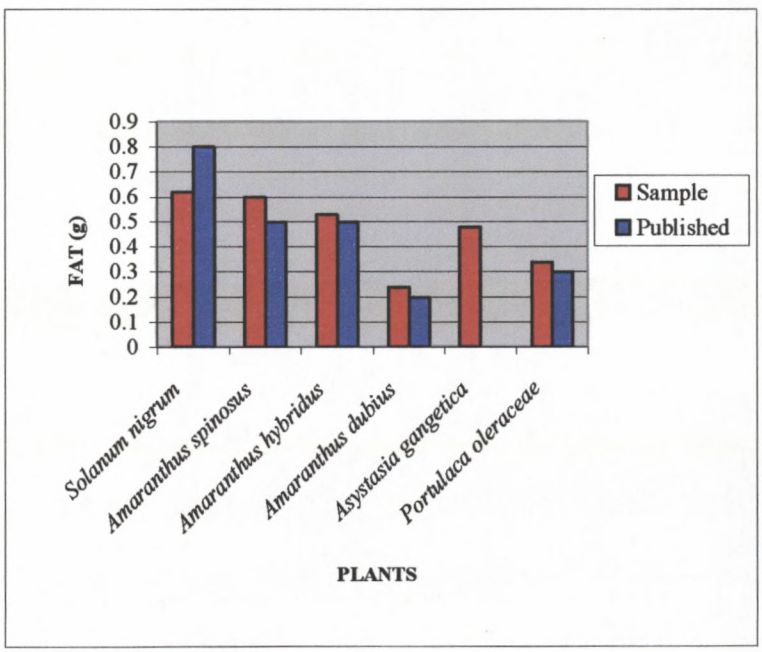

Fig. 3.4 Fat content of sample and published values (Maundu *et al.*, 1999) of six leafy vegetables per 100 g

The fat content of *Asystasia gangetica* was not documented in the published database.

3.2.5 Fibre Content

The leaves of *Bidens pilosa* (2.92 g 100 g^{-1}) are an excellent source of fibre whilst the lowest quantity of fibre was found in the leaves of *Portulaca oleracea* (1.21 g 100 g^{-1}). Fifty percent of the leafy vegetables contained fibre values ranging between 2 g 100 g^{-1} and 3 g 100 g^{-1} (Table 3.8). These leafy vegetables in rank order are as follows: *Bidens pilosa* (2.92 g 100 g^{-1}), *Amaranthus dubius* (2.87 g 100 g^{-1}), *Amaranthus hybridus* (2.81 g 100 g^{-1}), *Momordica balsamina* (2.75 g 100 g^{-1}), *Senna occidentalis* (2.58 g 100 g^{-1}), *Amaranthus spinosus* (2.48 g 100 g^{-1}), *Solanum nigrum* and *Cucumis metuliferus* (2.42 g 100 g^{-1}), *Cleome monophylla* (2.14 g 100 g^{-1}) and *Cerathotheca triloba* (2.07 g 100 g^{-1}).

The remaining fifty percent of leafy vegetables that comprise fibre values between 1 g 100 g^{-1} and 2 g 100 g^{-1} include *Physalis viscosa* (1.97 g 100 g^{-1}), *Chenopodium album* and *Centella asiatica* (1.92 g 100 g^{-1}), *Oxygonum sinuatum* (1.68 g 100 g^{-1}), *Asystasia gangetica* (1.63 g 100 g^{-1}), *Emex australis* (1.57 g 100 g^{-1}), *Justicia flava* (1.39 g 100 g^{-1}), *Wahlenbergia undulata* (1.33 g 100 g^{-1}), *Galinsoga parviflora* (1.24 g 100 g^{-1}) and *Portulaca oleracea* (1.21 g 100 g^{-1}).

The fibre content of the published and sample values of the six leafy vegetables are exhibited in Fig. 3.25. The sample values for the fibre content of four of the leafy vegetables were appreciably higher than the published values. These plants included *Solanum nigrum*, *Amaranthus spinosus*, *Asystasia gangetica* and *Portulaca oleracea*. The sample values of *Solanum nigrum* (2.42 g 100 g^{-1}) and *Amaranthus spinosus* (2.48 g 100 g^{-1}) were approximately fifty percent greater than the published values of these leafy vegetables having values of 1.3 g 100 g^{-1}. There was a difference of 0.3 g 100 g^{-1} to 0.4 g 100 g^{-1} between the sample and published values of *Asystasia gangetica* (1.3 g 100 g^{-1}) and *Portulaca oleracea* (0.8 g 100 g^{-1}).

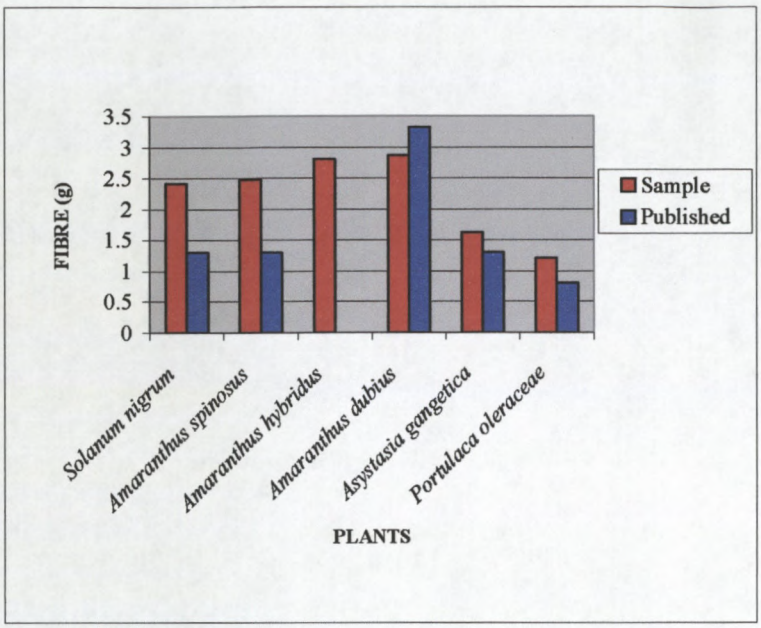

Fig. 3.5 Fibre content of sample and published values (Maundu *et al.*, 1999) of six leafy vegetables per 100 g

The published value of *Amaranthus dubius* (3.30 g 100 g^{-1}) was slightly higher than the sample value containing an amount of 2.87 g 100 g^{-1}. No results were available for *Amaranthus hybridus* in the published database.

3.2.6 Ash Content

The ash content ranged from 1.71 g 100 g^{-1} (*Galinsoga parviflora)* to 4.91 g 100 g^{-1} (*Amaranthus hybridus).* Other high values include the leaves of *Senna occidentalis* (4.23 g 100 g^{-1}), *Amaranthus dubius* (3.42 g 100 g^{-1}), *Justicia flava* (3.32 g 100 g^{-1}) and *Cleome monophylla* (3.01 g 100 g^{-1}).

Thirteen of the leafy vegetables analysed contained 2 g 100 g^{-1} to 3 g 100 g^{-1} ash, namely *Chenopodium album* (2.94 g 100 g^{-1}), *Asystasia gangetica* (2.84 g 100 g^{-1}), *Bidens pilosa* (2.82 g 100 g^{-1}), *Amaranthus spinosus* (2.76 g 100 g^{-1}), *Cucumis metuliferus* (2.73 g 100 g^{-1}), *Emex australis* (2.62 g 100 g^{-1}), *Centella asiatica* (2.54 g 100 g^{-1}), *Ceratotheca triloba* (2.27 g 100 g^{-1}), *Physalis viscosa* (2.25 g 100 g^{-1}),

Solanum nigrum (2.24 g 100 g^{-1}), *Oxygonum sinuatum* (2.16 g 100 g^{-1}), *Momordica balsamina* (2.07 g 100 g^{-1}) and *Wahlenbergia undulata* (2.05 g 100 g^{-1}).The leaves of *Portulaca oleracea* and *Galinsoga parviflora* contained the lowest values of 1.86 g 100 g^{-1} and 1.74 g 100 g^{-1}, respectively.

Fig 3.26 represents the ash content of the published and sample values of the six leafy vegetables. There was a slight variation in the ash content between the published and sample values. The ash content of the samples were higher in *Solanum nigrum* (2.24 g 100 g^{-1}) and *Amaranthus spinosus* (2.76 g 100 g^{-1}) as compared to the published values of 2.0 g 100 g^{-1} and 2.6 g 100 g^{-1}, respectively. The published values of the remaining four leafy vegetables namely, *Amaranthus hybridus* (5.2 g 100 g^{-1}), *Amaranthus spinosus* (3.45 g 100 g^{-1}), *Asystasia gangetica* (2.95 g 100 g^{-1}) and *Portulaca oleracea* (2.5 g 100 g^{-1}) contained a higher levels of ash than the sample values.

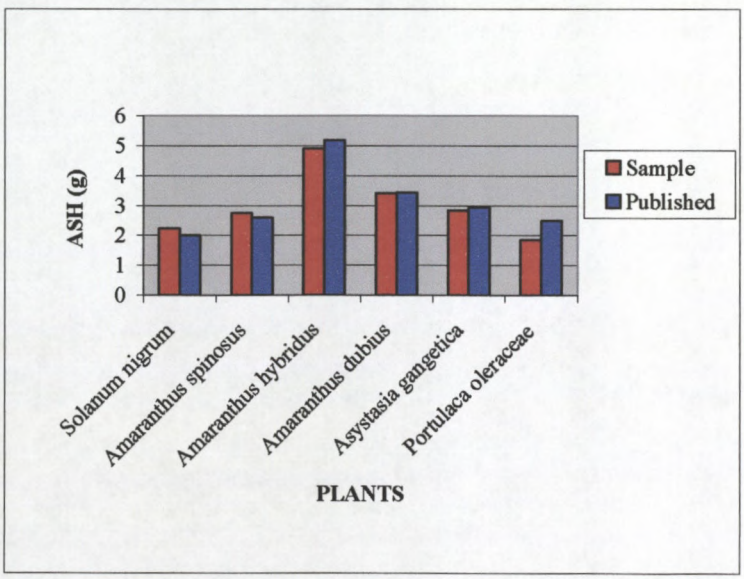

Fig. 3.6 Ash content of sample and published values (Maundu *et al.*, 1999) of six leafy vegetables per 100 g

3.2.7 Carbohydrate Content

The carbohydrate content of the leaf samples varied considerably, ranging from 1.16 g 100 g^{-1} to 12.79 g 100 g^{-1}. The richest sources of carbohydrates were found in the leaves of *Wahlenbergia undulata* (12.76 g 100 g^{-1}), *Physalis viscosa* (9.81 g 100 g^{-1}), *Senna occidentalis* (9.37 g 100 g^{-1}), *Solanum nigrum* (9.03 g 100 g^{-1}), *Justicia flava* (8.77 g 100 g^{-1}), *Chenopodium album* (8.34 g 100 g^{-1}), *Ceratotheca triloba* (8.28 g 100 g^{-1}), *Asystasia gangetica* (8.27 g 100 g^{-1}) and *Amaranthus dubius* (7.86 g 100 g^{-1}).

The leaves of *Momordica balsamina* (6.82 g 100 g^{-1}), *Amaranthus hybridus* (6.09 g 100 g^{-1}), *Cucumis metuliferus* (5.55 g 100 g^{-1}) and *Galinsoga parviflora* (5.29 g 100 g^{-1}) were found to contain appreciable amounts of carbohydrates. Low values were reported for the leaves of *Centella asiatica* (3.81 g 100 g^{-1}), *Bidens pilosa* (3.72 g 100 g^{-1}), *Cleome monophylla* (3.40 g 100 g^{-1}), *Oxygonum sinuatum* (2.85 g 100 g^{-1}), *Emex australis* (2.73 g 100 g^{-1}) and *Portulaca oleracea*. The leaves of *Amaranthus spinosus* (1.16 g 100 g^{-1}) were the poorest source of carbohydrates.

The graphical representation of the carbohydrate content of the six sample and published values are shown in Fig 3.27. A higher quantity of carbohydrates was found in the sample values of *Solanum nigrum* (9.03 g 100 g^{-1}) as compared to the published value of 5.7 g 100 g^{-1}. The published values for four of the leafy vegetables were found to contain substantially greater amounts of carbohydrates. The published and sample values for *Amaranthus spinosus*, *Amaranthus hybridus*, *Amaranthus dubius* and *Portulaca oleracea* are as follows: (6.5 g 100 g^{-1} and 1.16 g 100 g^{-1}), (15.30 g 100 g^{-1} and 6.09 g 100 g^{-1}), (11.79 g 100 g^{-1} and 7.86 g 100 g^{-1}) and (4.2 g 100 g^{-1} and 2.65 g 100 g^{-1}), respectively. No carbohydrate value for *Asystasia gangetica* has been reported in the published database.

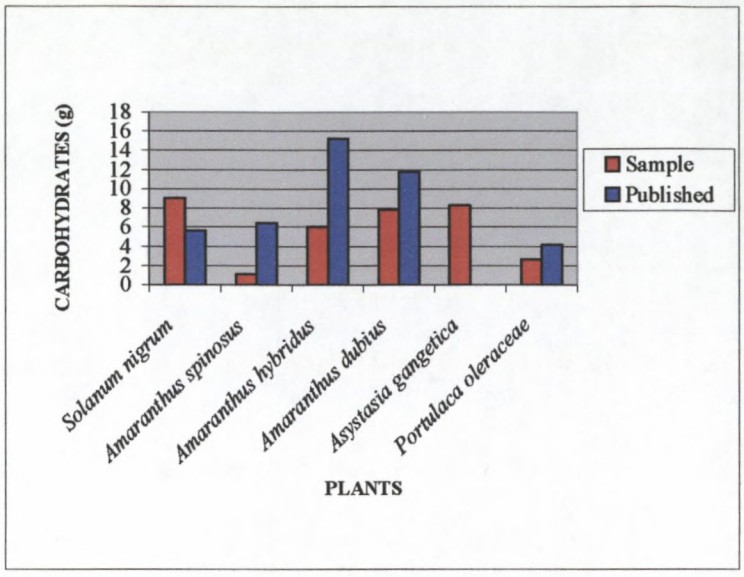

Fig. 3.7 Carbohydrate content of sample and published values (Maundu *et al.*, 1999) of six leafy vegetables per 100 g

3.3 MICRONUTRIENT COMPOSITION OF SAMPLE AND PUBLISHED VALUES

Mean values for micronutrient content of nutritional importance are presented in (Table 3.11). These values were determined by using the raw data from Appendix 9. The results of the mineral concentrations in this study are extremely high for most minerals. Since such high values were obtained, subsequent analyses were conducted using the atomic absorption spectrophotometer. However, the values obtained were in accordance to the values obtained using ICP technology. Vegetables are richer in mineral substances as compared with fruits. The mineral substance content is normally between 0.60 and 1.80% and more than 60 elements are present (Dauthy, 1995).

Vitamin results were not included in this study since the results were very low possibly due to a low extraction efficiency.

Table 3.4 Micronutrient content of traditional leafy vegetables studied (per 100 g dry weight ± SD)

PLANT	Ca (mg 100 g^{-1})	P (mg 100 g^{-1})	Na (mg 100 g^{-1})	Cu (mg 100 g^{-1})	Zn (mg 100 g^{-1})	Mg (mg 100 g^{-1})	Mn (mg 100 g^{-1})	Fe (mg 100 g^{-1})
Solanum nigrum	2067.48 ± 7.25	478.01 ± 0.39	431.34 ± 2.21	6.30 ± 0.14	23.49 ± 1.87	276.86 ± 1.15	2.77 ± 0.17	84.53 ± 0.35
Physalis viscosa	1166.97 ± 9.52	616.25 ± 6.46	363.79 ± 1.51	3.60 ± 0.21	14.48 ± 1.71	535.21 ± 0.64	1.73 ± 0.07	19.82 ± 0.65
Cucumis metuliferus	2974.40 ± 8.6	434.25 ± 7.17	317.36 ± 2.26	2.58 ± 0.11	11.10 ± 1.44	1021.76 ± 13.07	3.74 ± 0.23	20.24 ± 0.18
Momordica balsamina	2688.20 ±153.24	355.90 ± 3.24	376.24 ± 1.51	2.68 ± 0.27	11.83 ± 1.73	612.68 ± 1.78	9.60 ± 0.51	22.84 ± 2.33
Amaranthus spinosus	3930.58 ± 15.3	628.60 ± 7.23	392.92 ± 3.03	3.36 ± 0.34	15.47 ± 0.86	1165.64 ± 2.57	3.02 ± 0.07	31.92 ± 2.46
Amaranthus hybridus	2363.26 ± 0.41	603.94 ± 1.00	427.10 ± 0.18	2.38 ± 0.33	17.93 ± 0.28	1316.88 ± 2.28	24.38 ± 0.91	21.2 ± 0.54
Amaranthus dubius	1686.20 ± 0.44	487.40 ± 0.24	346.99 ± 1.06	2.76 ± 0.17	56.12 ± 1.47	805.63 ± 2.14	81.92 ± 0.92	25.11 ± 0.34
Asystasia gangetica	2565.89 ± 0.81	813.75 ± 0.61	932.81 ± 0.96	3.59 ± 0.17	6.99 ± 0.17	960.56 ± 1.19	18.07 ± 0.23	20.77 ± 1.19
Justicia flava	2072.53 ± 0.95	292.30 ± 0.27	580.96 ± 0.83	5.54 ± 0.24	10.68 ± 1.13	1408.86 ± 3.8	8.4 ± 0.18	16.31 ± 0.08
Emex australis	1601.79 ± 17.17	290.43 ± 8.19	332.39 ± 0.41	0.77 ± 0.2	20.38 ± 2.52	1017.64 ± 2.59	30.59 ± 2.29	15.21 ± 0.51
Oxygonum sinuatum	1474.33 ± 0.25	472.81 ± 1.26	1459.78 ± 5.64	3.82 ± 0.11	7.49 ± 0.49	520.95 ± 3.3	4.38 ± 0.35	39.39 ± 1.51
Bidens pilosa	1353.61 ± 191.11	504.42 ± 7.98	289.99 ± 1.23	9.67 ± 1.06	22.64 ± 3.1	657.78 ± 0.44	20.83 ± 1.12	17.33 ± 0.1
Cleome monophylla	3203.29 ± 0.62	784.18 ± 0.37	25.35 ± 0.04	2.17 ± 0.3	5.43 ± 0.65	370.59 ± 1.06	10.16 ± 0.16	23.57 ± 1.27
Portulaca oleracea	1360.61 ± 0.75	333.07 ± 0.45	148.24 ± 0.16	3.38 ± 0.27	34.10 ± 0.54	1036.59 ± 1.02	23.76 ± 0.82	42.06 ± 0.33
Wahlenbergia undulata	1305.30 ± 283.59	308.45 ± 13.53	373.71 ± 3.96	2.43 ± 0.24	41.32 ± 1.88	193.34 ± 1.2	7.25 ± 1.77	18.96 ± 0.98
Senna occidentalis	2230.44 ± 13.38	417.35 ± 5.74	346.72 ± 1.05	2.09 ± 0.33	9.14 ± 0.57	854.14 ± 2.62	6.73 ± 0.07	10.88 ± 0.04
Chenopodium album	1489.65 ± 25.1	797.31 ± 0.65	682.68 ± 0.64	3.58 ± 0.55	108.72 ± 2.91	1238.56 ± 1.53	26.99 ± 1.65	12.6 ± 0.25
Ceratotheca triloba	705.22 ± 0.51	222.67 ± 1.34	114.76 ± 0.54	3.36 ± 0.21	2.66 ± 0.2	427.79 ± 1.71	8.03 ± 0.38	18.55 ± 0.33
Galinsoga parviflora	161.82 ± 1.68	38.02 ± 0.68	35.78 ± 1.15	3.41 ± 0.27	13.65 ± 0.11	681.42 ± 1.68	43.97 ± 1.32	27.3 ± 0.35
Centella asiatica	2425.27 ±0.13	326.94 ± 1.16	15.78 ± 0.08	6.69 ± 0.44	19.86 ± 1.37	271.38 ± 0.65	22.81 ± 0.23	18 ± 0.34

3.3.1 Calcium Content

The RDA of calcium for adults is 800 mg per day (Food and Nutrition Board, 1989) and 90% of the leafy vegetables analysed in this study meets the requirements for calcium. The leafy vegetables analysed in this study contained remarkably high amounts of calcium (>1000 mg 100 g^{-1}) except for the leaves of *Ceratotheca triloba* (705.22 mg 100 g^{-1}) and *Galinsoga parviflora* containing the lowest amount of 161.82 mg 100 g^{-1}. The leafy vegetable that contained the highest quantity of calcium was *Amaranthus spinosus* (3930.58 mg 100 g^{-1}) followed by *Cleome monophylla* (3203.29 mg 100 g^{-1}).

Eight of the twenty leafy vegetables analysed contained amounts between 2000 mg 100 g^{-1} to 3000 mg 100 g^{-1} mg 100 g^{-1} of calcium, namely *Cucumis metuliferus* (2974.40 mg 100 g^{-1}), *Momordica balsamina* (2688.20 mg 100 g^{-1}), *Asystasia gangetica* (2565.89 mg 100 g^{-1}), *Centella asiatica* (2425.27 mg 100 g^{-1}), *Amaranthus hybridis* (2363.26 mg 100 g^{-1}), *Senna occidentalis* (2230.44 mg 100 g^{-1}), *Justicia flava* (2072.53 mg 100 g^{-1}) and *Solanum nigrum* (2067.48 mg 100 g^{-1}). The following leafy vegetables contained between 1000 mg 100 g^{-1} and 2000 mg 100 g^{-1} calcium: *Amaranthus dubius* (1686.20 mg 100 g^{-1}), *Emex australis* (1601.79 mg 100 g^{-1}), *Chenopodium album* (1489.65 mg 100 g^{-1}), *Oxygonum sinuatum* (1474.33 mg 100 g^{-1}), *Portulaca oleracea* (1360.61 mg 100 g^{-1}), *Bidens pilosa* (1353.61 mg 100 g^{-1}), *Wahlenbergia undulata* (1305.30 mg 100 g^{-1}) and *Physalis viscosa* (1166.97 mg 100 g^{-1}).

The calcium concentrations obtained for the six leafy vegetables used in this study are outstanding when compared to the published values as exhibited in Fig. 3.28. The sample values for *Solanum nigrum*, *Amaranthus spinosus*, *Amaranthus hybridus* and *Portulaca oleracea* were 2067.48 mg 100 g^{-1}, 3930.58 mg 100 g^{-1}, 2363.26 mg 100 g^{-1} and 1360.61 mg 100 g^{-1}, respectively, whereas the published values of 442 mg 100 g^{-1}, 267 mg 100 g^{-1}, 553 mg 100 g^{-1}, and 379 mg 100 g^{-1} were reported for *Solanum nigrum*, *Amaranthus spinosus*, *Amaranthus hybridus* and *Portulaca oleracea*, respectively. No data was reported for *Amaranthus dubius* and *Asystasia gangetica* in the published database.

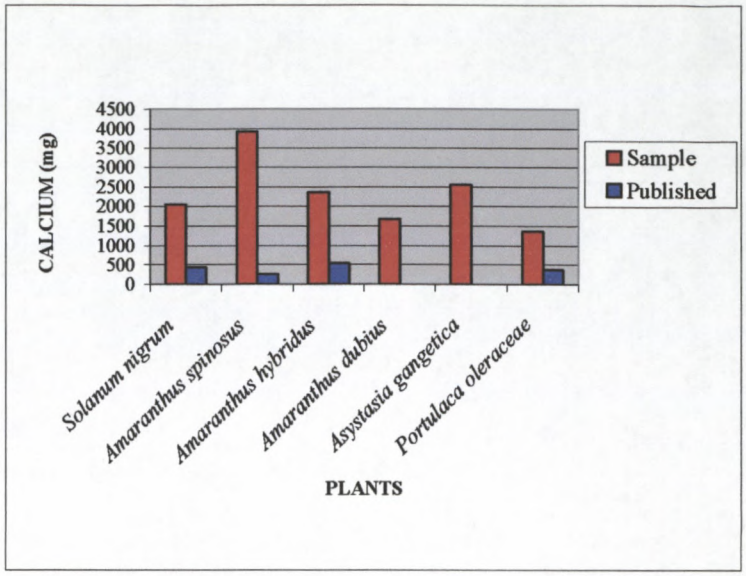

Fig. 3.8 Calcium content of sample and published values (Maundu *et al.*, 1999) of six leafy vegetables per 100 g

3.3.2 Phosphorus Content

The phosphorus content of the leaves varied greatly and ranged from 38.02 mg 100 g^{-1} (*Galinsoga parviflora*) to 813.75 mg 100 g^{-1} (*Asystasia gangetica*). The richest sources of phosphorus were found in leaves of *Chenopodium album* (797.31 mg 100 g^{-1}), *Cleome monophylla* (784.18 mg 100 g^{-1}), *Amaranthus spinosus* (628.60 mg 100 g^{-1}), *Physalis viscosa* (616.25 mg 100 g^{-1}) and *Amaranthus hybridus* (603.94 mg 100 g^{-1}) and *Bidens pilosa* (504.42 mg 100 g^{-1}).

Other high phosphorus values were found in *Amaranthus dubius* (487.40 mg 100 g^{-1}), *Solanum nigrum* (mg 100 g^{-1}), *Oxygonum sinuatum* (472.81 mg 100 g^{-1}), *Cucumis metuliferus* (434.25 mg 100 g^{-1}) and *Senna occidentalis* (417.35 mg 100 g^{-1}). Eight of the twenty leafy vegetables analysed contained phosphorus concentrations between 200 mg 100 g^{-1} and 400 mg 100 g^{-1}, namely *Momordica balsamina* (355.90 mg 100 g^{-1}), *Portulaca oleracea* (333.07 mg 100 g^{-1}), *Centella asiatica* (326.94 mg 100 g^{-1}), *Wahlenbergia undulata* (308.45 mg 100 g^{-1}), *Justicia flava* (292.30 mg 100 g^{-1}), *Emex*

australis (290.43 mg 100 g^{-1}), and *Ceratotheca triloba* (222.67 mg 100 g^{-1}). The RDA for phosphorus is 800 mg per day for adults (Food and Nutrition Board, 1989).

Fig 3.29 represents the phosphorus content of the sample and published values of the six leafy vegetables. Remarkably high phosphorus levels were found in the leafy vegetables used in this study. The sample value for *Solanum nigrum* was 478.01 mg 100 g^{-1} whilst a value of 75 mg 100 g^{-1} was documented for the published value. There was roughly a ten-fold difference between the sample and published value of *Amaranthus spinosus* (628.60 mg 100 g^{-1} and 67 mg 100 g^{-1}, respectively).

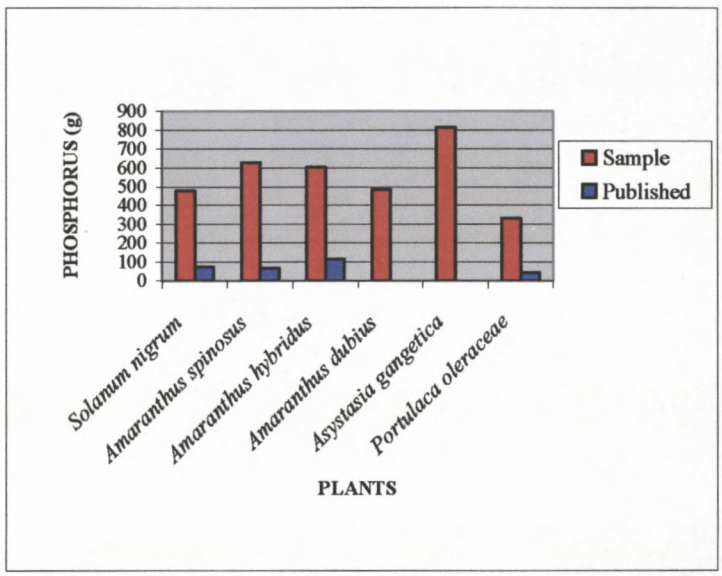

Fig. 3.9 Phosphorus content of sample and published values (Maundu *et al.*, 1999) of six leafy vegetables per 100 g

The phosphorus levels for the sample value of *Amaranthus hybridus* (603.94 mg 100 g^{-1}) was approximately six times greater than the published value of 116 mg 100 g^{-1}. *Portulaca oleracea* contained a much higher protein value of 333.07 mg 100 g^{-1} in the sample than the published value (43.08 mg 100 g^{-1}). No values were reported in the published database for *Amaranthus dubius* and *Asystasia gangetica*.

3.3.3 Sodium Content

Noteworthy is outstanding sodium concentration in the leaves of *Oxygonum sinuatum* (1459.78 mg 100 g^{-1}) and *Asystasia gangetica* (932.81 mg 100 g^{-1}). Other high sodium species included *Chenopodium album* (682.68 mg 100 g^{-1}), *Justicia flava* (580.96 mg 100 g^{-1}) and *Solanum nigrum* (431.34 mg 100 g^{-1}) as shown in Table 3.14. Leafy vegetables samples that contained substantial and similar quantities of sodium were *Amaranthus hybridus* (427.10 mg 100 g^{-1}), *Amaranthus spinosus* (392.92 mg 100 g^{-1}), *Momordica balsamina* (376.24 mg 100 g^{-1}), *Wahlenbergia undulata* (373.71 mg 100 g^{-1}), *Physalis viscosa* (363.79 mg 100 g^{-1}), *Amaranthus dubius* (346.99 mg 100 g^{-1}), *Senna occidentalis* (346.72 mg 100 g^{-1}), *Emex australis* (332.39 mg 100 g^{-1}), *Cucumis metuliferus* (317.36 mg 100 g^{-1}) and *Bidens pilosa* (289.99 mg 100 g^{-1}).

Low levels of sodium were detected for *Centella asiatica* (317.36 mg 100 g^{-1}) and *Bidens pilosa* (289.99 mg 100 g^{-1}). Low levels of sodium were detected for *Centella asiatica* (15.78 mg 100 g^{-1}), *Cleome monophylla* (25.35 mg 100 g^{-1}), *Galinsoga parviflora* (35.78 mg 100 g^{-1}), and A*maranthus hybridus* (42.71 mg 100 g^{-1}). Sixty five percent of the leafy vegetables meet the RDA of sodium, which is 300 mg per day for adults (Food and Nutrition Board, 1989).

Fig. 3.30 is representative of the sodium content of the published and sample values of the six leafy vegetables. The sample results for *Amaranthus hybridus* and *Portulaca oleracea* revealed sodium concentrations of 427.10 mg 100 g^{-1} and 148.24 mg 100 g^{-1}, respectively, whilst published values of 6.54 mg 100 g^{-1} and 38.41 mg 100 g^{-1} were reported. No values were reported for *Solanum nigrum*, *Amaranthus spinosus*, *Amaranthus dubius* and *Asystasia gangetica* in the published database.

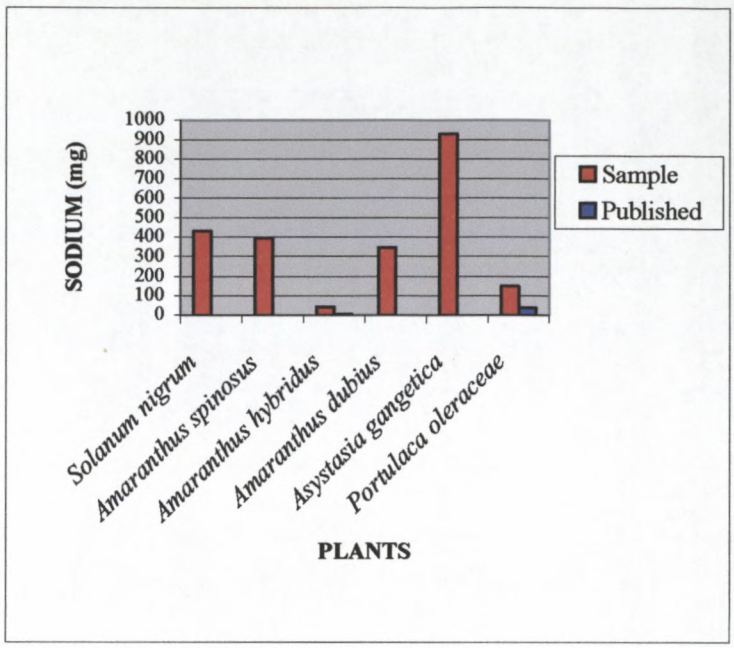

Fig 3.10 Sodium content of sample and published values (Maundu *et al.*, 1999) of six leafy vegetables per 100 g

3.3.4 Copper Content

The highest quantity of copper (9.67 mg 100 g^{-1}) was found in the leaves of *Bidens pilosa*, followed by *Centella asiatica* (6.69 mg 100 g^{-1}), *Solanum nigrum* (6.30 mg 100 g^{-1}) and *Justicia flava* (5.54 mg 100 g^{-1}) as shown in Table 3.15. There was a narrow range of 2.07 mg 100 g^{-1} to 3.82 mg 100 g^{-1} for all other leafy vegetables analysed with the exception of *Emex australis*, which contained a copper concentration of 0.77 mg 100 g^{-1}.

Forty percent of the leafy vegetables analysed exhibited levels of copper between 3 mg 100 g^{-1} and 4 mg 100 g^{-1}. These leafy vegetables included *Oxygonum sinuatum* (3.82 mg 100 g^{-1}), *Physalis viscosa* (3.60 mg 100 g^{-1}), *Asystasia gangetica* (3.59 mg 100 g^{-1}), *Chenopodium album* (3.58 mg 100 g^{-1}), *Galinsoga parviflora* (3.41 mg 100 g^{-1}), *Portulaca oleracea* (3.38 mg 100 g^{-1}), *Amaranthus spinosus* (3.36 mg 100 g^{-1}), and *Ceratotheca triloba* (3.36 mg 100 g^{-1}). Sodium levels of <3 mg 100 g^{-1} were found in the leaves of *Amaranthus dubius* (2.76 mg 100 g^{-1}), *Momordica balsamina* (2.68 mg

100 g^{-1}), *Cucumis metuliferus* (2.58 mg 100 g^{-1}), *Wahlenbergia undulata* (2.43 mg 100 g^{-1}), *Amaranthus hybridus* (2.38 mg 100 g^{-1}), *Cleome monophylla* (2.17 mg 100 g^{-1}), *Senna occidentalis* (2.09 mg 100 g^{-1}) and *Emex australis* (0.77 mg 100 g^{-1}). All the leafy vegetables except for *Emex australis* meet the daily requirement for copper, which is 2 mg per day for adults (Food and Nutrition Board, 1989).

3.3.5 Zinc Content

The richest source of zinc was found in *Chenopodium album* (108.72 mg 100 g^{-1}) whilst the poorest source was *Ceratotheca triloba* (2.66 mg 100 g^{-1}) (Table 3.16).

Appreciable amounts of zinc were found in *Amaranthus dubius* (56.12 mg 100 g^{-1}) and *Portulaca oleracea* (34.10 mg 100 g^{-1}). There was an approximate difference of 1 mg 100 g^{-1} amongst seventy five percent of the leafy vegetables analysed. These leafy vegetables are *Solanum nigrum* (23.49 mg 100 g^{-1}), *Bidens pilosa* (22.64 mg 100 g^{-1}), *Emex australis* (20.38 mg 100 g^{-1}), *Centella asiatica* (19.86 mg 100 g^{-1}), *Amaranthus hybridus* (17.93 mg 100 g^{-1}), *Amaranthus spinosus* (15.47 mg 100 g^{-1}), *Physalis viscosa* (14.48 mg 100 g^{-1}), *Galinsoga parviflora* (13.65 mg 100 g^{-1}), *Momordica balsamina* (11.83 mg 100 g^{-1}), *Cucumis metuliferus* (11.10 mg 100 g^{-1}), *Justicia flava* (10.68 mg 100 g^{-1}), *Senna occidentalis* (9.14 mg 100 g^{-1}), *Oxygonum sinuatum* (7.49 mg 100 g^{-1}), *Asystasia gangetica* (6.99 mg 100 g^{-1}) and *Cleome monophylla* (5.43 mg 100 g^{-1}).

The RDA of zinc is 10 mg per day for adults (Food and Nutrition Board, 1989) and is exceeded by most of the leafy vegetables.

3.36 Magnesium Content

The daily requirement of magnesium is 120 mg per day for adults (Food and Nutrition Board, 1989) and is surpassed by all the leafy vegetables evaluated in this study. As shown in Table 3.17, all the plants analysed were excellent sources of magnesium ranging from 193.34 mg 100 g^{-1} (*Wahlenbergia undulata*) to 1408.86 mg 100 g^{-1} (*Justicia flava*). Thirty five percent of the total leafy vegetables evaluated, contained

magnesium levels >1000 mg 100 g^{-1}. These leafy vegetables include *Justicia flava* (1408.86 mg 100 g^{-1}), *Amaranthus hybridus* (1316.88 mg 100 g^{-1}), *Chenopodium album* (1238.56 mg 100 g^{-1}), *Amaranthus spinosus* (1165.64 mg 100 g^{-1}), *Portulaca oleracea* 1036.59 mg 100 g^{-1}), *Cucumis metuliferus* (1021.76 mg 100 g^{-1}), and *Emex australis* (1017.64 mg 100 g^{-1}). Comparatively high values were found in leaves of *Asystasia gangetica* (960.56 mg 100 g^{-1}), *Senna occidentalis* (854.14 mg 100 g^{-1}) and *Amaranthus dubius* (805.63 mg 100 g^{-1}).

Magnesium levels ranging between 500 mg 100 g^{-1} and 700 mg 100 g^{-1} were found in the leaves of *Galinsoga parviflora* (681.42 mg 100 g^{-1}), *Bidens pilosa* (657.78 mg 100 g^{-1}), *Momordica balsamina* (612.68 mg 100 g^{-1}), *Physalis viscosa* (535.21 mg 100 g^{-1}), and *Oxygonum sinuatum* (520.95 mg 100 g^{-1}). Significant quantities of magnesium were reported for the remaining leafy vegetables analysed, namely *Ceratotheca triloba* (427.79 mg 100 g^{-1}), *Cleome monophylla* (370.59 mg 100 g^{-1}), *Solanum nigrum* (276.86 mg 100 g^{-1}), *Centella asiatica* (271.38 mg 100 g^{-1}) and *Wahlenbergia undulata* (193.34 mg 100 g^{-1}).

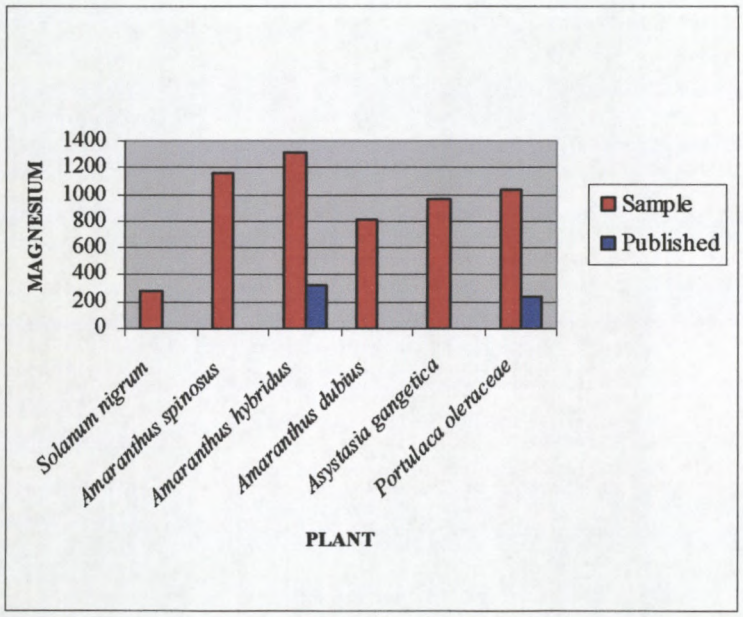

Fig 3.11 Magnesium content of sample and published values (Maundu *et al.*, 1999) of six leafy vegetables per 100 g

The magnesium content of the sample and published values are presented in Fig. 3.31. Magnesium levels of the test samples were very high. Sample values of 1316.88 mg 100 g^{-1} and 1036.59 mg 100 g^{-1} and published values of 329 mg 100 g^{-1} and 242 mg 100 g^{-1} were reported for the leaves of *Amaranthus hybridus* and *Portulaca oleracea*, respectively.

3.3.7 Manganese Content

The manganese content of the leaves ranged from 1.73 mg 100 g^{-1} in *Physalis viscosa* to a remarkably high 81.92 mg 100 g^{-1} in *Amaranthus dubius* as presented in (Table 3.18). The leaves of *Galinsoga parviflora* (43.97 mg 100 g^{-1}), *Emex australis* (30.59 mg 100 g^{-1}), *Chenopodium album* (26.99 mg 100 g^{-1}), A*maranthus hybridus* (24.38 mg 100 g^{-1}), P*ortulaca oleracea* (23.76 mg 100 g^{-1}), *Centella asiatica* (22.81 mg 100 g^{-1}) and *Bidens pilosa* (20.83 mg 100 g^{-1}) also contained an abundant source of manganese.

There was a difference of approximately 1 mg 100 g^{-1} in eleven of the leafy vegetables analysed. These leafy vegetables included *Cleome monophylla* (10.16 mg 100 g^{-1}), *Momordica balsamina* (9.60 mg 100 g^{-1}), *Justicia flava* (8.40 mg 100 g^{-1}), *Ceratotheca triloba* (8.03 mg 100 g^{-1}), *Wahlenbergia undulata* (7.25 mg 100 g^{-1}), *Senna occidentalis* (6.73 mg 100 g^{-1}), *Oxygonum sinuatum* (4.38 mg 100 g^{-1}), *Cucumis metuliferus* (3.74 mg 100 g^{-1}), *Amaranthus spinosus* (3.02 mg 100 g^{-1}), *Solanum nigrum* (2.77 mg 100 g^{-1}) and *Physalis viscosa* (1.73 mg 100 g^{-1}). Seventy percent of the leafy vegetables assayed in this study meet the RDA for manganese of 7 mg per day for adults (Food and Nutrition Board, 1989).

3.3.8 Iron Content

All the leafy vegetables evaluated contain substantial quantities of iron and conforms to the RDA of 10 mg per day for adults (Food and Nutrition Board, 1989). The leaves of *Solanum nigrum* are outstanding in terms of iron content, at 84.53 mg 100 g^{-1} as shown in Table 3.19. Other good sources of iron were found in the leaves of *Portulaceae*

oleracea (42.06 mg 100 g^{-1}), *Oxygonum sinuatum* (39.39 mg 100 g^{-1}) and *Amaranthus spinosus* (31.92 mg 100 g^{-1}).

Iron concentrations of between 20 mg 100 g^{-1} and 30 mg 100 g^{-1} were found in thirty five percent of leafy vegetables namely *Galinsoga parviflora* (27.30 mg 100 g^{-1}), *Amaranthus dubius* (25.11 mg 100 g^{-1}), *Cleome monophylla* (23.57 mg 100 g^{-1}), *Momordica balsamina* (22.84 mg 100 g^{-1}), *Amaranthus hybridus* (21.20 mg 100 g^{-1}), *Asystasia gangetica* (20.77 mg 100 g^{-1}) and *Cucumis metuliferus* (20.24 mg 100 g^{-1}).

Forty five percent of the leafy vegetables contained an appreciable quantity of iron that ranged between 10 mg 100 g^{-1} and 20 mg 100 g^{-1}. These leafy vegetables include *Physalis viscosa* (19.82 mg 100 g^{-1}), *Wahlenbergia undulata* (18.96 mg 100 g^{-1}), *Ceratotheca triloba* (18.55 mg 100 g^{-1}), *Centella asiatica* (18.00 mg 100 g^{-1}), *Bidens pilosa* (17.33 mg 100 g^{-1}), *Justicia flava* (16.31 mg 100 g^{-1}), *Emex australis* (15.21 mg 100 g^{-1}), *Chenopodium album* (12.60 mg 100 g^{-1}) and *Senna occidentalis* (10.88 mg 100 g^{-1}).

As shown graphically in (Fig. 3.32), the sample values for iron of the six leafy vegetables are higher than the published values. A sample value of 84.53 mg 100 g^{-1} was reported for *Solanum nigrum* whilst a low published value of 1 mg 100 g^{-1} was documented. There was a 12 % increase in the leaves of *Amaranthus spinosus* having a sample value of 31.92 mg 100 g^{-1} and a published value of 3.90 mg 100 g^{-1}. The leaves of *Amaranthus hybridus* exhibited a sample value of 21.2 mg 100 g^{-1} and 10.2 mg 100 g^{-1} as the published value, thereby showing a 50 % increase. The published value for the leaves of *Portulaca oleracea* was 15.56 mg 100 g^{-1} and approximately three times lower then the sample value of 42.06 mg 100 g^{-1}.

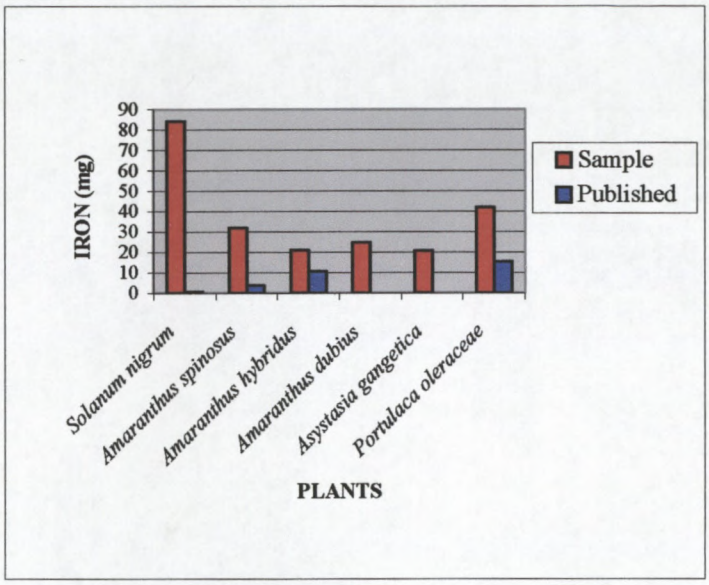

Fig. 3.12 Iron content of samples and published values (Maundu *et al.*, 1999) of six leafy vegetables per 100 g

No values were documented for *Amaranthus dubius* and *Asystasia gangetica* in the published database.

3.4 COMPARISON OF ENERGY AND PROXIMATE COMPOSITION OF FIVE RAW AND COOKED LEAFY VEGETABLES

The mean values of the proximate composition and energy analysis of the five selected raw and cooked leafy vegetables are shown in (Table 3.20). The raw data used to calculate the mean values is available in Appendix 10. Energy values for the cooked leafy vegetables analysed ranged from 130.35 kJ 100 g^{-1} to 294.11 kJ 100 g^{-1}. The energy content of the cooked samples of four of the leafy vegetables, namely, *Amaranthus dubius*, *Wahlenbergia undulata*, *Galinsoga parviflora* and *Centella asiatica* increased whilst a decrease for *Oxygonum sinuatum* was observed. It should be noted that the energy content is dependent on the protein, fat and carbohydrate content according to the Atwater's factors. The moisture, fat and carbohydrate content of the cooked samples increased whilst the protein, fibre and ash content decreased.

Table 3.5 Energy and proximate composition of five raw and cooked traditional leafy vegetables per 100 g

Plants	Form	Energy (kJ)	Moisture (%)	Protein (g)	Fat (g)	Fibre (g)	Ash (g)	Carbohydrates (g)
Amaranthus dubius	Raw	205.79	84.59	3.89	0.24	2.87	3.42	7.86
Amaranthus dubius	**Cooked**	**193.56**	**87.81**	**2.15**	**0.52**	**2.12**	**1.28**	**8.24**
Oxygonum sinuatum	Raw	108.63	91.94	2.58	0.47	1.68	2.16	2.85
Oxygonum sinuatum	**Cooked**	**135.80**	**92.61**	**1.78**	**0.69**	**1.04**	**0.68**	**4.24**
Wahlenbergia undulata	Raw	313.28	79.64	5.23	0.32	1.33	2.05	12.76
Wahlenbergia undulata	**Cooked**	**294.11**	**82.42**	**2.55**	**0.58**	**0.95**	**0.74**	**13.71**
Galinsoga parviflora	Raw	170.58	88.71	3.75	0.51	1.24	1.74	5.29
Galinsoga parviflora	**Cooked**	**168.06**	**90.40**	**1.33**	**0.95**	**0.86**	**0.75**	**6.57**
Centella asiatica	Raw	219.01	87.78	3.15	2.72	1.92	2.54	3.81
Centella asiatica	**Cooked**	**200.10**	**91.13**	**1.37**	**2.86**	**1.26**	**0.62**	**3.92**

3.4.1 *Amaranthus dubius*

The raw *Amaranthus dubius* sample contained a higher energy value of 205.79 kJ 100 g^{-1} as compared to the cooked sample that yielded an energy value of 193.56 kJ 100 g^{-1}. There was a 3.22% increase in the moisture content in the cooked sample (87.81%), whilst 84.59% was accounted for the raw sample. Cooking resulted in a protein loss of 44.73%; protein values for raw and cooked samples were 3.89 g 100 g^{-1} and 2.15 g 100 g^{-1}, respectively. There was approximately a two-fold increase in the fat content with raw sample containing 0.24 g 100 g^{-1} and 0.52 g 100 g^{-1} for the cooked sample. The fibre content was reduced by 26.13% in the cooked sample (2.12 g 100 g^{-1}), whilst the raw sample contained a value of 2.87 g 100 g^{-1}. The ash content of the cooked sample (1.28 g 100 g^{-1}) decreased considerably as compared to the raw sample (3.42 g 100 g^{-1}) with a reduction value of 62.57%. There was an increase of 4.83 % in the carbohydrate content of the cooked sample (8.24 g 100 g^{-1}) with the raw sample containing 7.86 g 100 g^{-1}.

3.4.2 *Oxygonum sinuatum*

The level of energy yielded by the cooked sample of *Oxygonum sinuatum* (130.35 kJ 100 g^{-1}) was higher than the raw sample that yielded an amount of 108.63 kJ 100 g^{-1}. The moisture content of the cooked sample of *Oxygonum sinuatum* increased slightly containing a value of 92.61% whilst the raw sample contained a value of 91.94%. The protein content of the cooked sample (1.78 g 100 g^{-1}) was reduced by 31% as compared to the raw sample constituting 2.58 g 100 g^{-1} of protein. There was an increase of 46.81% in the cooked sample having a fat value of 0.69 g 100 g^{-1} whilst the raw sample contained 0.47 g 100 g^{-1}. The fibre values of the cooked and raw samples were 1.04 g 100 g^{-1} and 1.68 g 100 g^{-1}, respectively, resulting in a 61.54% loss of the former sample. The ash content of the cooked sample (0.68 g 100 g^{-1}) was reduced by 68.5%, with the raw sample containing 2.16 g 100 g^{-1} of ash. The carbohydrate content of the cooked sample increased to 4.01 g 100 g^{-1} with the raw sample displayed an amount of 2.85 g 100 g^{-1}, thereby resulting in a 41.70% loss.

3.4.3 *Wahlenbergia undulata*

The cooked leaves of *Wahlenbergia undulata* yielded an energy content of 294.11 kJ 100 g^{-1} whilst the raw leaves constituted 313.28 kJ 100 g^{-1}. There was a slight increase in the moisture content of the cooked sample (82.42 g 100 g^{-1}) as compared to the raw sample (79.64%). The protein content of the raw sample (5.23 g 100 g^{-1}) was significantly greater than the cooked sample containing an amount of 2.55 g 100 g^{-1} with a 51.24% loss in the latter sample. There was an 81.25% increase in the fat content of the cooked sample (0.58 g 100 g^{-1}) as compared to 0.32 g 100 g^{-1} for the raw sample. There was a 0.38 g 100 g^{-1} difference in the fibre content between the raw (1.33 g 100 g^{-1}) and cooked (0.95 g 100 g^{-1}) samples with a 28.57% loss in the latter sample. The ash content of the cooked sample (0.74 g 100 g^{-1}) was reduced by 65.74% whilst 2.05 g 100 g^{-1} was found in the raw sample. A higher carbohydrate value of 13.71 g 100 g^{-1} was found in the cooked sample as compared to 12.76 g 100 g^{-1} in the raw sample.

3.4.4 *Galinsoga parviflora*

The energy values for the raw and cooked leaves of *Galinsoga parviflora* were 170.58 kJ 100 g^{-1} and 168.06 kJ 100 g^{-1}, respectively, resulting in a slight energy loss of the latter sample. There was an increase of 1.69% in the moisture content between the cooked (90.40%)and raw sample (88.71%). Protein was denatured by 64.53% from 3.75 g 100 g^{-1} in the raw sample to 1.33 g 100 g^{-1} in the cooked sample. The fat content of the cooked sample increased to 0.95 g 100 g^{-1} from a value of 0.51 g 100 g^{-1} recorded for the raw sample resulting in a fat increase of 86.27%. There was a difference of 30.64% in the fibre content of the raw (1.24 g 100 g^{-1}) and cooked (0.86 g 100 g^{-1}) sample. Ash content was reduced from 1.74 g 100 g^{-1} in the raw sample to 0.75 g 100 g^{-1} in the cooked sample, resulting in a 56.90% loss. The carbohydrate content of the cooked sample increased by 24.20%, containing a quantity of 6.57 g 100 g^{-1} whilst 5.29 g 100 g^{-1} was found in the raw sample.

3.4.5 *Centella asiatica*

The energy content of the raw and cooked leaves of *Centella asiatica* was 219.01 kJ 100 g^{-1} and 200.10 kJ 100 g^{-1}, respectively. There was a 3.35% difference in the moisture content between the two samples with the cooked sample constituting 91.13% and the raw sample containing 87.78% of moisture. The protein content was reduced considerably by 56.51% from 3.15 g 100 g^{-1} in the raw sample to 1.37 g 100 g^{-1} in the cooked sample. There was a slight increase of 5.15% in the fat content of the cooked sample to 2.86 g 100 g^{-1} as compared to 2.72 g 100 g^{-1} found in the raw sample. The fibre content of the cooked sample was reduced significantly by 34.38% containing an amount of 1.26 g 100 g^{-1} whilst a value of 1.92 g 100 g^{-1} was recorded for the raw sample. There was a drastic loss of 75.59% in the ash content of the cooked sample (0.62 g 100 g^{-1}) as compared to the raw sample (2.54 100 g^{-1}). Carbohydrate content of the cooked sample increased slightly from 3.81 g 100 g^{-1} in the raw sample to 3.92 g 100 g^{-1} in the cooked sample.

3.5 COMPARISON OF MICRONUTRIENT COMPOSITION OF FIVE RAW AND COOKED LEAFY VEGETABLES

Table 3.21 represents the mean micronutrient concentrations of the six selected raw and cooked leafy vegetables used in this study. Mean values were calculated using the raw data found in Appendix 11. The results of the processed leafy vegetables indicate a reduction in all the micronutrient elements.

Table 3.6 Micronutrient content of five raw and cooked traditional leafy vegetables per 100 g

Plants	Form	Ca (mg)	P (mg)	Na (mg)	Cu (mg)	Zn (mg)	Mg (mg)	Mn (mg)	Fe (mg)
Amaranthus dubius	Raw	1686.20	487.40	346.99	2.76	56.12	805.63	81.92	25.11
Amaranthus dubius	**Cooked**	**1166.43**	**146.29**	**312.59**	**0.12**	**4.15**	**120.45**	**4.46**	**16.87**
Oxygonum sinuatum	Raw	1474.33	472.81	1459.78	3.82	7.49	520.95	4.38	39.39
Oxygonum sinuatum	**Cooked**	**1235.66**	**198.07**	**535.60**	**0.22**	**0.11**	**82.45**	**0.64**	**36.64**
Wahlenbergia undulata	Raw	1305.30	308.45	373.71	2.43	41.32	193.34	7.25	18.96
Wahlenbergia undulata	**Cooked**	**544.62**	**161.25**	**252.34**	***ND**	**3.61**	**19.37**	**0.86**	**8.95**
Galinsoga parviflora	Raw	161.82	38.02	35.78	3.41	13.65	681.42	43.97	27.3
Galinsoga parviflora	**Cooked**	**130.26**	**24.88**	**29.22**	***ND**	**0.53**	**225.14**	**6.73**	**7.36**
Centella asiatica	Raw	2425.27	326.94	15.78	6.69	19.86	271.38	22.81	18.00
Centella asiatica	**Cooked**	**1289.22**	**153.09**	**11.02**	**1.49**	**0.78**	**26.16**	**2.04**	**8.75**

*ND = not detected

3.5.1 *Amaranthus dubius*

The cooked sample of *Amaranthus dubius* (1166.43 mg 100 g^{-1}) resulted in a loss of 30.82% of calcium as compared to the raw sample constituting 1686.20 mg 100 g^{-1}. Phosphorus in the cooked sample was reduced drastically from 487.40 mg 100 g^{-1} in the raw sample to 146.29 mg 100 g^{-1} resulting in a 69.99% loss. There was a 9.91% loss of sodium in the cooked sample (312.59 mg 100 g^{-1}) whilst the raw sample contained 346.99 mg 100 g^{-1}. The copper value decreased drastically by 95.65% with the raw sample containing 2.76 mg 100 g^{-1} whilst a value of 0.12 mg 100 g^{-1} was recorded for the cooked sample. A great reduction of 92.61% of zinc was noticed in the cooked sample (4.15 mg 100 g^{-1}) whilst the raw sample had 56.12 mg 100 g^{-1}. Magnesium was reduced from 805.63 mg 100 g^{-1} in the raw sample to 120.45 mg 100 g^{-1} in the cooked sample resulting in an 85.055% loss. A loss of 94.55% was noted for the zinc content of the cooked sample, whilst the iron content of the cooked sample resulted in a 32.82% loss.

3.5.2 *Oxygonum sinuatum*

There was a 16.19% reduction in the calcium content of the cooked *Oxygonum sinuatum* leaves, having a value of 1235.66 whilst 1474.33 mg 100 g^{-1} of calcium was recorded for the raw leaves. The phosphorus content of the cooked sample resulted in a loss of 58.11%, having values of 472.81 mg 100 g^{-1} and 198.07 mg 100 g^{-1} for raw and cooked samples, respectively. The sodium content of the cooked sample was decreased from 1459.78 mg 100 g^{-1} to 535.60 mg 100 g^{-1} with a major loss of 63.31%. A 94.24% loss in copper concentration of the cooked sample was determined with values of 3.82 mg 100 g^{-1} and 0.22 mg 100 g^{-1} recorded for the raw and cooked samples, respectively. The zinc content of the cooked sample was reduced from 7.49 mg 100 g^{-1} to 0.11 mg 100 g^{-1} resulting in a 98.53% loss. Magnesium content of the cooked leaves was reduced drastically by 84.17% from 520.95 mg 100 g^{-1} to 82.45 mg 100 g^{-1}. There was an 85.39% reduction in the manganese content of the cooked sample having a value of 0.64 mg 100 g^{-1}, whilst a value of 0.4.38 mg 100 g^{-1} was documented for the raw leaves. A slight reduction in the iron content was noted for the cooked leaves (336.64 mg 100 g^{-1}) as compared to the raw leaves (39.39 mg 100 g^{-1}).

3.5.3 *Wahlenbergia undulata*

The cooked leaves of *Wahlenbergia undulata* (544.62 mg 100 g^{-1}) were 58.28% lower than the raw leaves having a value of 1305.30 mg 100 g^{-1}. There was a similar reduction in the phosphorus content of the cooked leaves having a value of 161.25 mg 100 g^{-1} whilst the raw leaves contained a value of 308.45 mg 100 g^{-1} thereby resulting in a 47.72% loss. The highest percentage mineral loss of the cooked leaves was found in zinc, which was reduced by 92.26%.

There was an approximate ten-fold magnesium decrease in the cooked sample containing a value of 19.37 mg 100 g^{-1} whilst 193.34 mg 100 g^{-1} was found in the raw sample. The manganese content of the raw (7.25 mg 100 g^{-1}) and cooked (0.86 mg 100 g^{-1}) samples varied markedly with an 88.14% reduction in the cooked leaves. Iron was determined as 8.95 mg 100 g^{-1} in cooked and 18.96 mg 100 g^{-1} in raw samples with the latter resulting in a 52.79% reduction. Copper was not detected in the cooked sample of *Wahlenbergia undulata.*

3.5.4 *Galinsoga parviflora*

Calcium was reduced from 161.82 mg 100 g^{-1} in the raw sample to 130.26 mg 100 g^{-1} in the cooked sample, incurring a loss of 19.50%. Phosphorus decreased from 38.02 mg 100 g^{-1} to 24.88 mg 100 g^{-1} indicating a 34.56% loss. There was a slight difference in the sodium content between the raw (35.78 mg 100 g^{-1}) and cooked (29.22 mg 100 g^{-1}) leaves of *Galinsoga parviflora* with a reduction of 18.33%. Zinc was reduced drastically by 96.12% in the cooked leaves exhibiting a value of 13.65 mg 100 g^{-1} whilst a quantity of 0.53 mg 100 g^{-1} was noted for the raw sample. Magnesium and magnesium concentrations of the cooked samples decreased significantly, resulting losses of 66.96% and 84.69%, respectively. The iron concentrations for the raw and cooked leaves were 27.30 mg 100 g^{-1} and 7.36 mg 100 g^{-1}, resulting in a 73.04% loss of the cooked sample. Copper was not detected in the sample.

3.5.5 *Centella asiatica*

Calcium was reduced by 46.84% in the cooked sample (1289.22 mg 100 g^{-1}) of *Centella asiatica* whilst the raw sample contained 2425.27 mg 100 g^{-1}. An amount of 153.09 mg 100 g^{-1} of phosphorus was found in the cooked leaves as compared to raw leaves having a concentration of 326.94 mg 100 g^{-1}, resulting in a 53.17% loss in the cooked sample. A loss of 30.16% of sodium was found in the cooked leaves (11.02 mg 100 g^{-1}) whilst a value of 15.78 mg 100 g^{-1} was documented for the raw leaves. The copper values for the raw and cooked samples were 6.69 mg 100 g^{-1} and 1.49 mg 100 g^{-1}, respectively with a 77.73% loss found in the cooked sample.

The highest mineral loss was found in zinc with a reduction value of 96.07%. There was a drastic magnesium reduction of 90.36% that was found in the cooked leaves (26.16 mg 100 g^{-1}) as compared to the raw leaves (271.38 mg 100 g^{-1}). A similar reduction of manganese (91.06%) was determined in the cooked leaves with a value of 2.04 mg 100 g^{-1} and a quantity of 22.81 mg 100 g^{-1} recorded for the raw leaves. The iron content was reduced from 18.00 mg 100 g^{-1} in the raw leaves to 8.75 mg 100 g^{-1} in the cooked leaves with a 51.39% l

CHAPTER FOUR: DISCUSSION

4.1 ENERGY AND PROXIMATE COMPOSITION OF SAMPLE AND PUBLISHED VALUES

Senna occidentalis (353.93 kJ 100 g^{-1}) and *Wahlenbergia undulata* (313.28 kJ 100 g^{-1}) yielded the highest energy levels and this data is higher than the values obtained for indigenous leafy vegetables studied by Maundu *et al.* (1999). It should be noted that 50% of the leafy vegetables analysed in this study contained between 200-300 kJ 100 g^{-1}.

The moisture content of the twenty leafy vegetables analysed ranged from 77.4% (*Senna occidentalis*) to 92.63% (*Portulaca oleracea*) thus corresponding with moisture content for green leafy commercial and indigenous leafy vegetables (Maundu *et al.*, 1999; Kruger *et al.*, 1998; Langenhoven *et al.*, 1991).

Senna occidentalis provided the most abundant source of protein (6.79 g 100 g^{-1}), followed by *Amaranthus hybridus* (5.92 g 100 g^{-1}), *Physalis viscosa* (5.62 g 100 g^{-1}), *Momordica balsamina* (5.34 g 100 g^{-1}) and *Wahlenbergia undulata* (5.23 g 100 g^{-1}). These leafy vegetables provide approximately 11% of the RDA for protein. Maundu *et al.* (1999) reported a protein content of 6.3 g kg^{-1} for *Amaranthus hybridus*. The protein content of Amaranthaceae evaluated in this study is in good agreement with those observed by Maundu *et al.* (1999) for the same family. The protein content of the twenty leafy vegetables assayed in this study is much higher than the protein content of commercial vegetables with the exception of certain legumes reported by Kruger *et al.* (1998) and Langenhoven *et al.* (1991), thus confirming that leaves of traditional leafy vegetables are a superior source of protein. The average protein values (4.17 g 100 g^{-1}) of the twenty leafy vegetables make up approximately 8% of the RDA, which is 50 g per day for adults (Food and Nutrition Board, 1989).

Centella asiatica, *Senna occidentalis* and *Ceratotheca triloba* contained the highest quantities of fat having values of 2.72 g 100 g^{-1}, 2.21 g 100 g^{-1} and 2.17 g 100 g^{-1},

respectively. These fat values are contrasted by those reported for commercial (Kruger *et al.*, 1998; Langenhoven *et al.*, 1991) and indigenous (Maundu, *et al.*, 1999) vegetables. The fat content of the remaining leafy vegetables analysed in this study ranged from 0.24 g 100 g^{-1} in *Amaranthus dubius* to 0.83 g 100 g^{-1} in *Physalis viscosa* and these findings conform to the previously published literature for commercial and indigenous vegetables by Kruger *et al.* (1998), Langenhoven *et al.* (1991) and Maundu, *et al.* (1999), respectively.

There was a slight variation in the fibre content of the investigated traditional leafy vegetables species that ranged from 1.21 g 100 g^{-1} (*Portulaca oleracea*) to 2.92 g 100 g^{-1} (*Bidens pilosa*). The fibre content of *Portulaca oleracea* is in good agreement with that reported by Gopalan *et al.* (1985). Fibre values for all the leafy vegetables used in this study were lower than most of leafy commercial and indigenous vegetables compiled by Langenhoven *et al.* (1991) but similar to values for indigenous leafy vegetables reported by Maundu, *et al.* (1999). The higher fibre values, against our findings, which were reported for indigenous leafy vegetables may be due to the differences in habitats and to environmental factors. The RDA for fibre is 30 g per day for adults (Food and Nutrition Board, 1989).

The ash content ranged from 1.71 g 100 g^{-1} (*Galinsoga parviflora*) to 4.91 g 100 g^{-1} (*Amaranthus hybridus).* Thirteen of the leafy vegetables analysed contained 2 g 100 g^{-1} to 3 g 100 g^{-1} ash, thus being in general agreement with those observed by other workers (Gopalan *et al.*, 1985; Kruger *et al.*, 1998; Langenhoven *et al.*, 1991; Maundu, *et al.*, 1999).

The carbohydrate content of the leaf samples varied considerably, ranging from 1.16 g 100 g^{-1} (*Amaranthus spinosus*) to 12.79 g 100 g^{-1} (*Wahlenbergia undulata*) with an average value of 6.33 g 100 g^{-1}. These findings contrast with the lower carbohydrate values reported for commercial vegetables by Kruger *et al.* (1998) and Langenhoven *et al.* (1991) but are comparable to the studies of many of the indigenous leafy vegetables conducted by Maundu *et al.* (1999).

4.2 MICRONUTRIENT COMPOSITION OF SAMPLE AND PUBLISHED VALUES

Calcium is an important mineral involved in the building of rigid structures to support the body (Osborne and Voogt, 1978 – cited by Aletor *et al.*, 2002), and was well furnished by the leafy vegetables evaluated in this study. Ninety percent of the leafy vegetables meet the RDA for calcium, which is 800 mg per day. The leafy vegetables analysed in this study contained exceptionally high concentrations of calcium (>1000 mg 100 g^{-1}) except for the leaves of *Ceratotheca triloba* (705.22 mg 100 g^{-1}) and *Galinsoga parviflora* containing the lowest amount of 161.82 mg 100 g^{-1}.

The calcium content of *Galinsoga parviflora* is comparable to the values obtained for commercial vegetables (Kruger *et al.*, 1998; Langenhoven *et al.*, 1991). The calcium content determined in this study in the leaves of *Chenopodium album* (1489.65 mg 100 g^{-1}) compared very well to that documented by Gopalan *et al.* (1985) having a value of 1452.00 mg 100 g^{-1} but contrasted with a low value of 125.59 mg 100 g^{-1} reported by Ogle and Grivetti. (1985b). The high values obtained in this study concurred with the calcium content of some commonly eaten West African leafy vegetables plants studied by Boukari *et al.* (2001), e.g. leaves of amaranth, sorrel, okra which contain concentrations of 3590 mg 100 g^{-1}, 3630 mg 100 g^{-1}, 2850 mg 100 g^{-1}, respectively.

The phosphorus ranged from 222.67 mg 100 g^{-1} in *Ceratotheca triloba* to 813.75 mg 100 g^{-1} in *Asystasia gangetica* with the exception of 38.02 mg 100 g^{-1} recorded for *Galinsoga parviflora*. In contrast, while Glew *et al.* (1997) recorded high concentrations of phosphorus in some leafy vegetables studied in Burkina Faso, the phosphorus values determined in this study were much lower but were significantly higher than those of commercial vegetables reported by Kruger *et al.* (1998) and Langenhoven *et al.* (1991). Twelve of the twenty leafy vegetables provide between 50-100% of the RDA, with *Asystasia gangetica* providing 100% of the RDA, which is 800 mg per day for adults (Food and Nutrition Board, 1989).

Remarkably high sodium concentrations were found in the leaves of *Oxygonum sinuatum* (1459.78 mg 100 g^{-1}) and *Asystasia gangetica* (932.81 mg 100 g^{-1}). Other high values ranged from 114.76 mg 100 g^{-1} in *Ceratotheca triloba* to 682.68 mg 100 g^{-1} in *Chenopodium album*. In general the sodium content recorded in the present study exceeded the data given in literature by Glew *et al.* (1997); Kruger *et al.* (1998); Langenhoven *et al.* (1991) and Ogle and Grivetti (1985a) with the exception of *Amaranthus hybridus* (42.71 mg 100 g^{-1}), *Galinsoga parviflora* (35.78 mg 100 g^{-1}), *Cleome monophylla* (25.35 mg 100 g^{-1}), *Centella asiatica* (15.78 mg 100 g^{-1}).

Currently no deficiency of sodium is observed in the human diet (Jaworska and Kmiecik, 1999), however, sixty percent of the leafy vegetables meet the RDA for sodium, which is 300 mg per day for adults. These plants are *Oxygonum sinuatum* (1459.78 mg 100 g^{-1}), *Asystasia gangetica* (932.81 mg 100 g^{-1}), *Chenopodium album* (682.68 mg 100 g^{-1}), *Justicia flava* (580.96 mg 100 g^{-1}), *Solanum nigrum* (431.34 mg 100 g^{-1}), *Momordica balsamina* (376.24 mg 100 g^{-1}), *Wahlenbergia undulata* (373.71 mg 100 g^{-1}), *Physalis viscosa* (363.79 mg 100 g^{-1}), *Amaranthus dubius* (346.99 mg 100 g^{-1}), *Senna occidentalis* (346.72 mg 100 g^{-1}), *Emex australis* (332.39 mg 100 g^{-1}) and *Cucumis metuliferus* (317.36 mg 100 g^{-1}). It should be noted that an excessive intake of sodium may cause high blood pressure, which may lead to a host of health problems (Jaworska and Kmiecik, 1999).

Copper concentrations ranged from 2.09 mg 100 g^{-1} in *Senna occidentalis* to 9.67 mg 100 g^{-1} in *Bidens pilosa* with the exception of *Emex australis* having the lowest value of 0.22 mg 100 g^{-1}, which compares well with commercial vegetables (Kruger *et al.*, 1998; Langenhoven *et al.*, 1991). The remaining leafy vegetables contained considerably higher copper concentrations when compared to previous literature. All the leafy vegetables except for *Emex australis* meet the daily requirement for copper, which is 2 mg per day for adults (Food and Nutrition Board, 1989), indicating that these leafy vegetables are useful in preventing a deficiency of copper, which results in anaemia and bone problems (Arntzen and Ritter, 1984).

Recent evidence indicates that poor zinc status is widespread, especially among populations with cereal-based diets (Brown and Wuehler, 2000). The RDA of zinc is 10 mg per day for adults (Food and Nutrition Board, 1989) and is surpassed by most of the leafy vegetables. These leafy vegetables are therefore useful in preventing zinc deficiency. There was a marked difference in the zinc content of the leafy vegetables analysed in this study with *Cerathotheca triloba* containing the lowest concentration of 2.66 mg 100 g^{-1} and *Chenopodium album* containing the highest concentration of 108.72 mg 100 g^{-1}. These values are significantly higher than commercial vegetables (Kruger *et al.*, 1998; Langenhoven *et al.*, 1991).

In general, magnesium is among the deficient elements in the human diet, while its daily consumption by adults should amount to 120 mg (Food and Nutrition Board, 1989). The leafy vegetables evaluated in this study surpasses the RDA of magnesium for adults. All the leafy vegetables analysed were excellent sources of magnesium ranging from 193.34 mg 100 g^{-1} (*Wahlenbergia undulata*) to 1408.86 mg 100 g^{-1} (*Justicia flava*). These contents approximate those evidenced in indigenous leafy vegetables studied by Glew *et al.* (1997), exceeding the values reported for commercial vegetables (Kruger *et al.*, 1998; Langenhoven *et al.*, 1991).

Seventy percent of the leafy vegetables assayed in this study meet the RDA for manganese of 7 mg per day for adults (Food and Nutrition Board, 1989). The manganese content of the leaves ranged from 1.73 mg 100 g^{-1} in *Physalis viscosa* to a remarkably high 81.92 mg 100 g^{-1} in *Amaranthus dubius* with an average value of 17.96 mg 100 g^{-1}, thus significantly higher than the commercial vegetables studied by Kruger *et al.* (1998) and Langenhoven *et al.* (1991).

The RDA of iron for adults is 10 mg per day (Food and Nutrition Board, 1989), this element frequently being deficient in the diet. Iron is necessary for optimal immune function and all the leafy vegetables evaluated contain substantial quantities of iron having an average value of 26.34 mg 100 g^{-1}, thus corresponding more or less to the values reported by Maundu *et al.* (1999) but substantially higher than the values

reported by Kruger *et al.* (1998) and Langenhoven *et al.* (1991) for commercial vegetables.

One of the not so surprising findings in this study was that, all of the leafy vegetables evaluated in this study appear to be well endowed with all of the essential nutrients required for human nutrition. The values obtained from this study in comparison to those available in the published literature showed much disagreement and some agreement in relation to micronutrient content. To explain the differences it should be noted that the chemical composition of leafy vegetables, including the content of compounds both beneficial and undesirable in the diet, is significantly affected by agro technical measures and also by the environmental conditions. The plant state of maturation, genetic variances and environmental factors are possible explanations for discrepancies observed (Nordeide *et al.*, 1996). Also, the data on leafy plants in this study are the few using ICP technology.

4.3 COMPARISON OF ENERGY AND PROXIMATE COMPOSITION OF FIVE RAW AND COOKED LEAFY VEGETABLES

Analysis of raw and cooked leaves of the six leafy vegetables revealed that cooking the plants increased the composition of fat, carbohydrates and moisture and decreased the composition of protein, ash and fibre. The greatest losses occur through extraction or leaching-out of the water-soluble nutrients. The second important group of processing methods is linked to cooking operations e.g. the blanching, boiling, steaming, pasteurization and sterilization treatments of a variety of foods. The impact is influenced by the solubility and heat-sensitivity of nutrients (Mueller, 1990).

4.4 COMPARISON OF MICRONUTRIENT COMPOSITION OF FIVE RAW AND COOKED LEAFY VEGETABLES

Analysis of the cooked samples revealed a decrease in the micronutrient content for the six leafy vegetables analysed in this study. This is possibly attributed to the heat processing process whereby the water was discarded and only the leaves were

incorporated as test samples and analysed. Some of the nutrients were most probably retained in the water that was used to cook the leaves. However, cooking losses of some essential nutrients may be in excess of 75% (Dauthy, 1995).

Foods are processed for many beneficial reasons: to preserve and extend shelf life, increase digestibility, increase nutrient bioavailability, improve palatability and texture, eliminate microorganisms, destroy toxins, remove inedible parts, destroy antinutritional factors, and create new types of foods. Unfortunately, an overall decrease in nutrient content can accompany many food processing techniques, with larger losses occurring under more strenuous conditions. In most cases, the benefits of food processing outweigh the nutrient losses (FAO, 1996).

Heat processing of the leafy vegetables resulted in dramatic losses and possible ways of improving micronutrient retention could be with blanching in a minimum amount of water to minimise leaching. Food processing and food preparation procedures should be optimized to maintain the bioavailability and nutrient content of the foods. Mild heating, minimal water, and controlled storage conditions usually enhance the nutrient value whereas excess heat, water, or harsh storage conditions are destructive (FAO, 1996).

CHAPTER FIVE: GENERAL CONCLUSIONS

One of the objectives of this study was to consult an available database that represents the nutritional values of indigenous leafy vegetables and also to determine the nutritional values of twenty leafy vegetables.

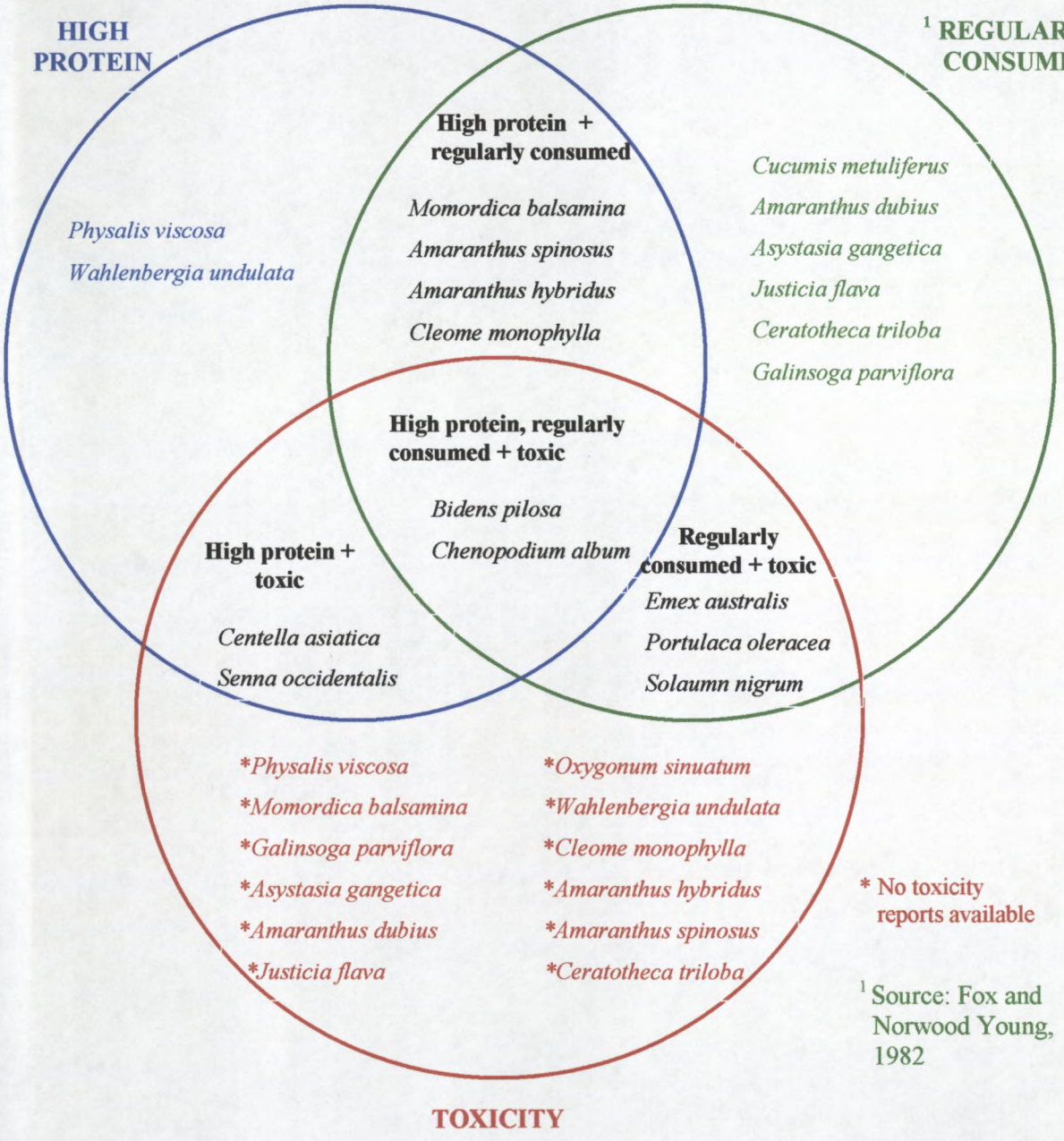

Fig. 5.1 Diagram showing the relationship between the protein content, frequency of consumption and toxicity of twenty leafy vegetables

Based on the results from mainly Fox and Norwood Young (1982), we found that *Cucumis metuliferus*, *Amaranthus dubius*, *Asystasia gangetica*, *Justicia flava*, *Ceratotheca triloba* and *Galinsoga parviflora* are regularly consumed by the African population and these leafy vegetables contain adequate amounts of protein and do not exhibit toxic properties (Fig. 5.1). The results from this study showed that *Momordica balsamina*, *Amaranthus spinosus*, *Amaranthus hybridus*, *Cleome monophylla*, *Bidens pilosa*, *Chenopodium album*, *Physalis viscosa*, *Wahlenbergia undulata*, *Senna occidentalis* and *Centella asiatica* provide excellent sources of protein, however *Physalis viscosa*, *Wahlenbergia undulata*, *Senna occidentalis* and *Centella asiatica* are regarded as famine foods by the African community. These leafy vegetables are suitable for introduction into cultivation. *Emex australis*, *Portulaca oleracea*, *Solanum nigrum* and *Chenopodium album* contain varying quantities of oxalic acid.

All the leafy vegetables evaluated in this study contain remarkable concentrations of minerals as presented in Fig. 5.2. *Amaranthus spinosus, Amaranthus dubius, Amaranthus hybridus, Momordica balsamina*, *Justicia flava*, *Cleome monophylla, Asystasia gangetica, Cucumis metuliferus*, *Galinsoga parviflora* and *Ceratotheca triloba* are regularly consumed by the African population (Fox and Norwood Young, 1982) and are excellent sources of minerals. *Bidens pilosa, Chenopodium album, Solanum nigrum, Portulaca oleracea, Emex australis* are also good sources of minerals and regularly consumed yet these leafy vegetables exhibit levels of toxicity.

Mineral concentrations exceed 1% of the plant dry weight, and generally are much higher than typical mineral concentrations in conventional edible leafy vegetables. These discoveries have raised the possibility that leafy vegetables can be used as a concentrated form of essential mineral nutritional supplements. The form of the mineral in the leafy vegetables can also offer a potential benefit, since the bioavailability, or amount of mineral taken up and utilized by the body, can be modified depending on the mineral source. Although plant components such as phytates can interfere with mineral uptake by the body, leafy vegetables are generally considered to be superior sources of supplements.

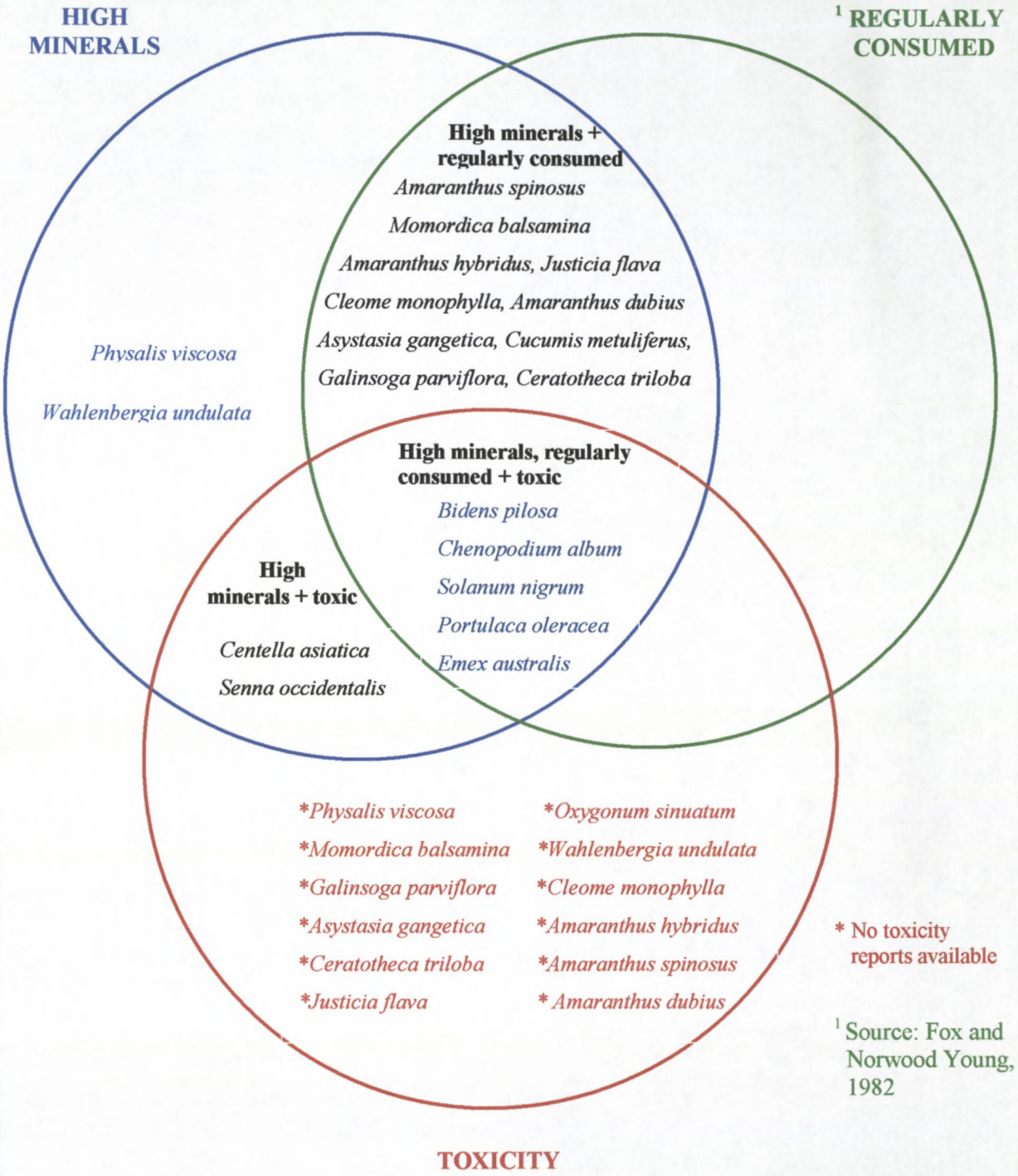

Fig. 5.2 Diagram showing the relationship between the mineral concentrations, frequency of consumption and toxicity of twenty leafy vegetables

This study shows that the following, *Momordica balsamina, Amaranthus spinosus, Amaranthus hybridus, Cleome monophylla, Amaranthus hybridus, Justicia flava, Amaranthus dubius, Asystasia gangetica, Cucumis metuliferus, Galinsoga parviflora and Ceratotheca triloba* have potential for further development since these leafy vegetables are regularly consumed by the African population and results from this study indicate their high nutritional values. Local communities should be informed about the benefits of these plants and knowledge thereof should be passed on to the younger generations.

Emex australis, *Portulaca oleracea*, *Solanum nigrum* and *Chenopodium album* contain varying quantities of oxalic acid, a colourless poisonous crystalline dicarboxylic acid which occurs naturally in many leafy vegetables. Oxalic acid may combine with calcium, iron, sodium, magnesium, or potassium to form less soluble salts known as oxalates. High levels of oxalic acid/oxalates in the diet lead to irritation of the digestive system, and particularly of the stomach and kidneys. They may also contribute to the formation of kidney stones (Agricultural Research Service, 1998). These leafy vegetables should be consumed in moderation. However, it is recommended that people suffering from kidney disease, kidney stones, rheumatoid arthritis, or gout should avoid these leafy vegetables. *Centella asiatica*, *Bidens pilosa* and *Senna occidentalis* should be eaten in reasonable quantities as consumption in large quantities pose a health risk.

Solanum nigrum, *Senna occidentalis* and *Centella asiatica* have been reported to be toxic if consumed in large amounts whilst the fruit of *Cucumis metuliferus* contains cucurbitacines that are harmful to both humans and animals. The quantity of consumption of these leafy vegetables by humans should be minimised, and measures should be taken to ensure that these leafy vegetables, which are dangerous to animals, do not grow excessively in grazing areas so that the risk of poisoning is reduced.

It may be said that in natural foods of our everyday diet there are thousands of toxic substances, which leads to the distinction between toxicity and hazard. The toxicity of a substance is its intrinsic capacity to produce injury when tested by itself. The hazard of a

substance is its capacity to produce injury under circumstances of exposure. Thus many substances have a high intrinsic toxicity but no hazard, when associated with its natural presence in foods. In spite of the multitude of toxic substances consumed daily in a normal diet by normal healthy individuals there is yet little evident hazard involved. There are three reasons for this. Firstly, the low concentrations of the toxicant present, second, because the effect of the many toxic substances present is not cumulative and lastly because of the antagonistic effect of one toxicant upon another. However, the situation could be different if a food were regularly eaten in excessive amounts (Fox and Norwood Young 1982).

Nutrient-rich foods are essential for proper development and growth both in adults and children and health educators should consider promoting the nutritional benefits of traditional and local leafy vegetables in rural communities, particularly by vulnerable groups such as children and pregnant women, as they can significantly contribute to the micronutrient content of the diet.

The nutritional analysis of the edible leafy vegetables of South Africa provides the value of these foods to those populations who rely upon them as staples or supplements to their diet. The diverse nutrition and health functions that these leafy vegetables serve in traditional culture, and indigenous knowledge of plant diversity, also offer potentially valuable solutions that enable biodiversity to address the problems facing contemporary society.

Further studies are required:

(i) to determine of toxicity levels of *Physalis viscosa*, *Oxygonum sinuatum*, *Momordica balsamina*, *Wahlenbergia undulata*, *Galinsoga parviflora*, *Cleome monophylla*, *Asystasia gangetica*, *Amaranthus hybridus*, *Amaranthus dubius*, *Amaranthus spinosus*, *Justicia flava and Ceratotheca triloba*,

(ii) to assess the bioavailability of the essential nutrients and the possible presence of antinutrients,

(iii) extensive or more productive cultivation for species that are already cultivated or semi-domesticated on a small scale,

(iv) extension of traditional utilization through improved processing, preservation, packaging and storage techniques, formulation and production of new products,

(v) development of nursery practices such as seed collection, germination and vegetative propagation and integration of the species into the traditional farming system, with field establishment trials using agroforestry techniques.

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APPENDICES

1 Catalyst mixture

192 g anhydrous sodium sulphate, 7 g copper sulphate crystals and 0.71 g selenium powder was mixed thoroughly using a mortar and pestle.

2 Preparation of filtering crucibles

Crucibles were ashed overnight at 525°C in a muffle furnace. Furnace temperature was allowed to drop to 130°C before crucibles were removed. Crucibles were soaked for 1 h in 2% cleaning solution at RT and then rinsed with water followed by de-ionised water. A volume of 15 ml acetone was used final rinse. Crucibles were then air dried. One gram of celite was added to dry crucibles and thereafter dried at 130°C to constant weight. Crucibles were cooled in desiccators for 1 h, and the weight recorded, to the nearest 0.1 mg, of crucible plus celite.

3 Preparation of 0.561M HCl

An aliquot of 93.5 ml 6N HCl was added to 700 ml water in a 1000 ml volumetric flask and made up to volume with water.

4 Preparation of MES-TRIS Buffer

0.05M MES, 0.05M TRIS, pH 8.2 at 24°C. 19.52 g MES and 12.2 g TRIS was dissolved in 1700 ml water. The pH was adjusted to 8.2 with 6N NaOH and diluted to 2:1 with water.

5 Standard retinol solutions

A 10 mg quantity of retinol was dissolved in 1 L ethanol and stored in the dark at 5°C. Standard solutions were prepared by diluting the stock solution with ethanol to give

final concentrations of 0.1, 0.2, and 0.4 mg/100ml. Solutions were used within two weeks of preparation.

6 Vitamin C standard solutions

Vitamin C stock solution was prepared by dissolving 1 g of ascorbic acid in 100 ml of metaphosphoric acid. Standard solutions of 0.1, 0.2 and 0.4 mg/ml were prepared using the stock solution.

7 Working stock solutions for minerals

Working stock solution s of 0.1 ppm, 0.25 ppm, 2.5 ppm and 7.5 ppm were prepared for iron, zinc, magnesium and manganese by pipetting 0.1 ml, 0.25 ml, 2.5 ml and 7.5 ml of 100 p pm mineral s tandards into 1 00 ml volumetric f lasks a nd making up to volume using double de-ionised water.

Working stock solutions of 0.1 ppm, 0.5 ppm, 1.0 ppm, 2.5 ppm and 5.0 ppm of copper were prepared b y p ipetting 0.1 ml, 0 .5 m l, 1 .0 ml, 2 .5 m l and 5.0 ml of the 100 m l mineral standards into100 ml volumetric flasks and making up to volume using double de-ionised water.

Sodium and phosphorus working stock solutions, at concentrations of 25 ppm, 75 ppm, 100 ppm, 150 ppm and 200 ppm were prepared by pipetting 25 ml, 75 ml, 100 ml, 150 ml and 200 ml of the mineral standards (1000 ppm) into 100 ml volumetric flasks and making up to volume using double de-ionised water.

Calcium at concentrations of 50 ppm, 100 ppm, 200 ppm, 300 ppm and 350 ppm were prepared by adding 50 ml, 100 ml, 200 ml, 300 ml and 350 ml of the calcium standard (1000 ppm) to 100 ml volumetric flasks and made up to volume using double de-ionised water.

8 Raw data results of energy and proximate analysis

Plants	Energy 1 kJ	Energy 2 kJ	Moisture 1 (%)	Moisture 2 (%)	Protein 1 (g)	Protein 2 (g)	Fat 1 (g)	Fat 2 (g)	Fibre 1 (g)	Fibre 2 (g)	Ash 1 (g)	Ash 2 (g)	Carbo-hydrates 1 (g)	Carbo-hydrates 2 (g)
Solanum nigrum	232.74	225.87	84.72	84.96	3.12	3.42	0.60	0.64	2.40	2.44	2.13	2.35	9.43	8.63
Physalis viscosa	294.48	284.78	81.28	81.70	5.58	5.66	0.79	0.87	1.92	2.02	2.12	2.38	10.23	9.39
Cucumis metuliferus	180.83	177.91	87.36	87.58	3.50	3.54	0.68	0.78	2.37	2.47	2.69	2.77	5.77	5.33
Momordica balsamina	219.26	225.04	85.48	85.07	5.12	5.56	0.46	0.52	2.72	2.78	2.00	2.14	6.94	6.71
Amaranthus spinosus	111.81	110.22	91.54	91.18	4.08	4.16	0.59	0.61	2.42	2.54	2.52	3.00	1.27	1.05
Amaranthus hybridus	221.98	220.15	82.50	82.60	5.89	5.95	0.47	0.59	2.79	2.83	4.83	4.99	6.31	5.87
Amaranthus dubius	209.80	201.77	84.32	84.86	3.83	3.95	0.20	0.28	2.84	2.90	3.40	3.44	8.25	7.47
Asystasia gangetica	204.78	210.48	85.61	85.11	3.01	3.09	0.52	0.44	1.60	1.66	2.81	2.87	8.05	8.49
Justicia flava	216.76	214.24	84.24	84.38	3.18	3.22	0.38	0.42	1.38	1.40	3.29	3.35	8.91	8.63
Emex australis	152.12	145.09	89.03	89.33	4.93	4.93	0.58	0.50	1.52	1.62	2.61	2.63	2.85	2.61
Oxygonum sinuatum	103.39	113.86	92.41	91.47	2.47	2.69	0.54	0.40	1.67	1.69	2.09	2.23	2.49	3.21
Bidens pilosa	164.68	163.01	88.05	88.19	4.70	4.82	0.54	0.62	2.83	3.01	2.79	2.85	3.92	3.52
Cleome monophylla	157.69	167.90	88.33	87.83	4.79	4.93	0.59	0.71	2.12	2.16	2.99	3.03	3.30	3.50
Portulaca oleraceae	100.76	97.99	97.99	92.72	2.51	2.53	0.31	0.37	1.18	1.24	1.83	1.89	2.81	2.49
Wahlenbergia undulata	305.32	321.23	80.16	79.12	5.19	5.27	0.30	0.34	1.30	1.36	1.98	2.12	12.37	13.15
Cassia occidentalis	356.85	351.00	77.26	77.53	6.74	6.84	2.17	2.25	2.56	2.60	4.14	4.32	9.69	9.06
Chenopodium album	246.06	244.55	83.32	83.40	4.58	4.62	0.74	0.78	1.88	1.96	2.91	2.97	8.45	8.23
Ceratotheca triloba	261.71	255.55	84.80	85.18	2.21	2.37	2.12	2.22	2.03	2.11	2.22	2.32	8.65	7.91
Galinsoga	176.15	165.01	88.43	88.99	3.72	3.78	0.48	0.54	1.18	1.30	1.65	1.83	5.72	4.86
Centella asiatica	219.39	218.63	87.76	87.80	2.98	3.32	2.69	2.75	1.89	1.95	2.50	2.58	4.07	3.55

9 Raw data results of micronutrient analysis

Plants	Ca 1	Ca 2	P 1	P 2	Na 1	Na 2	Cu 1	Cu 2	Mg 1	Mg 2	Mn 1	Mn 2	Fe 1	Fe 2	Zn 1	Zn 2
Solanum nigrum	2062.35	2072.61	477.73	478.28	429.78	432.90	6.20	6.40	277.67	276.05	2.89	2.65	84.77	84.28	22.16	24.81
Physalis viscosa	1160.24	1173.70	611.68	620.82	362.72	364.86	3.74	3.45	535.66	534.76	1.68	1.78	20.28	19.36	15.69	13.27
Cucumis metuliferus	2968.32	2980.48	429.18	439.32	315.76	318.96	2.50	2.66	1031.00	1012.51	3.90	3.58	20.37	20.11	10.08	12.12
Momordica balsamina	2796.56	2579.84	353.61	358.19	375.17	377.31	2.49	2.87	611.42	613.94	9.24	9.96	21.19	24.49	10.61	13.05
Amaranthus spinosus	3919.76	3941.40	633.71	623.49	390.78	395.06	3.12	3.60	1163.82	1167.46	3.07	2.97	30.18	33.66	14.86	16.08
Amaranthus hybridus	2362.97	2363.55	604.65	603.23	425.80	428.40	2.15	2.61	1315.27	1318.49	23.74	25.02	21.58	20.82	17.73	18.13
Amaranthus dubius	1685.89	1686.51	487.23	487.57	347.74	346.24	2.64	2.88	804.12	807.14	82.57	81.27	25.35	24.87	55.08	57.16
Asystasia gangetica	2565.32	2566.46	814.18	813.32	933.49	932.13	3.47	3.71	961.40	959.72	17.91	18.23	19.93	21.61	6.87	7.11
Justicia flava	2073.20	2071.86	292.49	292.11	581.55	580.37	5.37	5.71	1406.17	1411.55	8.53	8.27	16.25	16.37	9.88	11.48
Emex australis	1589.65	1613.93	284.64	296.22	332.68	332.10	0.63	0.91	1015.81	1019.47	32.21	28.97	15.57	14.85	18.59	22.16
Oxygonum sinuatum	1474.15	1474.51	473.70	471.92	1463.77	1455.79	3.89	3.74	518.62	523.28	4.13	4.63	38.32	40.46	7.84	7.14
Bidens pilosa	1488.74	1218.47	498.78	510.06	290.86	289.12	8.92	10.42	657.47	658.09	21.62	20.04	17.40	17.26	24.83	20.45
Cleome monophylla	3203.73	3202.85	783.92	784.44	25.32	25.38	1.96	2.38	369.84	371.34	10.05	10.27	22.67	24.47	4.97	5.89
Portulaca oleraceae	1361.14	1360.08	332.75	333.39	148.35	148.13	3.19	3.57	1035.87	1037.31	23.18	24.34	42.29	41.83	33.72	34.48
Wahlenbergia undulata	1104.77	1505.83	298.88	318.02	376.51	370.91	2.26	2.60	192.49	194.19	6.00	8.50	18.27	19.65	39.99	42.65
Cassia occidentalis	2239.90	2220.98	413.29	421.41	345.98	347.46	1.86	2.32	855.99	852.29	6.68	6.78	10.91	10.85	9.54	8.73
Chenopodium album	1507.40	1471.90	796.85	797.77	683.13	682.23	3.19	3.97	1239.64	1237.48	25.82	28.16	12.78	12.42	110.78	106.66
Ceratotheca triloba	704.86	705.58	223.62	221.72	114.38	115.14	3.21	3.51	426.58	429.00	7.76	8.30	18.78	18.32	2.80	2.52
Galinsoga	163.01	160.63	38.50	37.54	34.97	36.59	3.60	3.22	680.23	682.61	43.04	44.90	27.05	27.55	13.57	13.73
Centella asiatica	2425.18	2425.36	327.76	326.12	15.72	15.84	6.38	7.00	270.92	271.84	22.65	22.97	18.24	17.76	20.83	18.89

10 Raw data results of energy and proximate analysis of raw and cooked plants

Plants	Energy 1 kJ	Energy 2 kJ	Moisture1 (%)	Moisture 2 (%)	Protein 1 (g)	Protein 2 (g)	Fat 1 (g)	Fat 2 (g)	Fibre 1 (g)	Fibre 2 (g)	Ash 1 (g)	Ash 2 (g)	Carbohydrates (g)	Carbohydrates (g)
Amaranthus dubius	195.02	192.09	87.75	87.87	2.13	2.17	0.51	0.53	2.09	2.15	1.24	1.32	8.37	8.11
Oxygonum sinuatum	130.34	130.35	92.57	92.65	1.74	1.82	0.82	0.90	1.01	1.07	0.67	0.69	4.20	3.94
Wahlenbergia undulata	294.32	293.90	82.40	82.44	2.51	2.59	0.55	0.61	0.91	0.99	0.71	0.77	13.83	13.59
Galinsoga parviflora	169.99	166.13	90.32	90.48	1.27	1.39	0.93	0.97	0.83	0.89	0.69	0.81	6.79	6.35
Centella asiatica	201.09	199.08	91.08	91.18	1.35	1.39	2.92	3.00	1.25	1.27	0.56	0.68	4.09	3.75

11 Raw data results of micronutrient analysis of raw and cooked plants

Plants	Ca 1	Ca 2	P 1	P 2	Na 1	Na 2	Cu 1	Cu 2	Zn 1	Zn 2	Mg 1	Mg 2	Mn 1	Mn 2	Fe 1	Fe 2
Amaranthus dubius	1168.32	1164.54	147.73	144.85	309.23	315.95	0.10	0.14	4.32	3.98	121.62	119.28	4.94	3.98	17.08	16.65
Oxygonum sinuatum	1226.80	1244.51	196.07	200.06	534.14	537.06	0.20	0.23	0.09	0.13	80.83	84.07	0.70	0.58	37.56	35.71
Wahlenbergia undulata	544.87	544.37	160.76	161.74	249.82	254.86	*ND	*ND	3.69	3.53	21.12	17.62	0.92	0.80	8.67	9.23
Galinsoga parviflora	132.98	127.54	26.60	23.16	36.70	34.86	*ND	*ND	0.57	0.49	226.30	223.98	6.98	6.48	7.43	7.29
Centella asiatica	1286.54	1291.90	139.94	166.24	11.28	10.76	1.61	1.36	0.76	0.80	24.52	27.80	2.36	1.72	8.75	8.17