THE UTILIZATION OF *AMARANTHUS* LEAF POWDER TO SUPPLEMENT *UJEQE* (STEAMED BREAD) WHEAT FLOUR FOR THE ALLEVIATION OF FOOD AND NUTRITION INSECURITY IN EMPANGENI SOUTH AFRICA

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INYUVESI YAKWAZULU-NATALI

BY

Ruth Nachamada Olusanya

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DEDICATION

This thesis is dedicated to the Highest Authority in my life; the Almighty God ('I Am that I Am' Exodus 3:14) who gave me the breath of life to conduct the study and write this dissertation; May His name be exalted above the universe.

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DECLARATION OF RESEARCH OUTPUT

A. The following are the research outputs in DHET accredited Journals:

1. Chapter 2. Title of paper: - Underutilization versus Nutritional-Nutraceutical Potential of the *Amaranthus* Food Plant: A Mini-Review (Published in Applied Science MDPI Journal; 2021) Appl. Sci. 2021, 11(15), 6879; https://doi.org/10.3390/app11156879

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MND	Micronutrient deficiency
FAO	Food and Agriculture Organization
WHO	World Health Organization
PEM	Protein and Energy Malnutrition
MDG	Millennium Development Goal
SSA	Sub-Saharan Africa
SA	South Africa
NCDs	non-communicable diseases
ALP	*Amaranthus* leaf powder
A.	*Amaranthus*
ALPSU	*Amaranthus* leaf powder supplemented *Ujeqe.*

ABSTRACT

Malnutrition persists in many developing countries, leading to an increased concern in the farming sector to deliver at least 70% of food to feed 40% of the anticipated global population of nine billion persons by the year 2050. Such projections call for a keen interest in studies that explore underutilised edible crops for food and nutrition security of the world's growing population. Malnutrition of all forms including micronutrient deficiencies, "called hidden hunger", is currently an issue of concern. About 870 million people across the globe are unable to access sufficient nutritious food that optimises dietary needs. Also, 98% of this hungry population live in the developing countries, where 15% of the population is undernourished, Susceptible persons to malnutrition identified include infants, young children, and young women of childbearing age. The impact of malnutrition impairs children's vision at an early age, slows down cognitive development and retards general development. All forms of malnutrition are nutrient-related preventable challenges; however, it is identified as the leading factor to most morbidity and mortality rates; which limits the livelihoods of many individuals especially smallholder farmers who are residents in informal settlements of urban centres and rural communities. A food-based approach where available nutrient-dense food is incorporated as an ingredient in staple food has been identified as a good strategy to tackle malnutrition. *Amaranthus* is an ancient C4 plant, a drought tolerant plant that requires little attention yet maximum yield; with huge potential to provide food for nutrition security. Adequate nutrition, at the household level, is indispensable for the proper functioning of the human system and well-being. However, most marginalised, and less privileged people often follow a monotonous starchy/cereal-based diet as this is the available food to fall back on. Extensive studies have shown that about 30 000 varieties of edible plants are dispersed around the world. These plants are cheap, accessible, and highly endowed with medicinal and nutritional benefits. However, only 7000 have been utilised as food while others are underutilised including *Amaranthus*. It is perceived that most people harvesting *Amaranthus* leaves for food are the most disadvantaged and marginalised in the rural communities, thus preference issues, perceptions and stigma are linked to *Amaranthus* underutilisation. *Amaranthus* seeds have been investigated as enhancers of staple foods. Similarly, leaves of *Amaranthus* have been identified with great potential to enhance the nutritional value of staple foods for improved nutrition security, optimizing well-being, and improving livelihoods. However, Amaranthus leaves are yet to be explored as a supplement in many traditional foods, including *Ujeqe*. Online databases of peer-reviewed articles and books were reviewed around the nomenclature, nutritional, and nutraceutical value and objectives were conceived for this study. A mix design (qualitative and quantitative) research method was adopted and a purposive convenience random sampling approach was utilised for the study. Participatory Rural Appraisal (PRA) tools such as transact walks, observation and key informant interviews were conducted. Semi-structured open-ended questionnaires were used to conduct a series of face-to-face interview with six key informants in five markets (n = 30) from urban and rural formal and informal markets where commonly sold/consumed varieties of Amaranthus were identified. Semi-structured questionnaires (100) were administered to gather data around the utilisation of *Ujeqe* and *Amaranthus* leaves as potential food for improved nutrition security. A clustered data of (91) respondents was analysed, using descriptive content analysis. The findings of the survey show that *Ujeqe* is consumed as a meal or as a snack by all people except babies. Also, it is a special meal well appreciated for its simplicity of ingredients and the mode of preparation thus, it is a convenient food that can be served at any time of the day, even in ceremonies, religious functions, and traditional worship of ancestors. *Ujeqe's* complementary foods that were identified included legumes and protein-rich foods of animal origin including *Usu* which are less accessible to the less-privileged hence, some consume it alone as a snack or as a single food. Studies have shown that cereal-based foods without vegetables and fruits are inadequate for optimum well-being because they are lacking/limited in essential nutrients. *Amaranthus* plants have been investigated as food plant with essential nutrient. Its grains have been used as fortificants, but the leaves have been neglected and its application in *Ujeqe* steamed bread (USB) is rarely reported in the literature. *Amaranthus* seeds have been processed into flour and used as food fortificants in staple food. However, the processing of *Amaranthus* leaves is still very low. Thus, the most common species of *Amaranthus* grown and sold in formal and informal market in the study site (*Amaranthus dubius)* was sourced and self-processed into *Amaranthus* leaf powder (ALP) under a controlled food laboratory environment. The ALP was analysed for macro and micronutrients and utilised to develop 0%, 2%, 4% and 6% prototypes of ALP supplemented *Ujeqe* which was analysed for macronutrient and micronutrient content. The sensory attributes of ALP supplemented *Ujeqe* were evaluated using 60 untrained panellists. Moisture content of plain wheat flour (PWF) and ALP in the range 10.6-4.41g; were within the quality shelf-life before usage. The carbohydrate for this study (41.6-74.3g) and fat (1.58-4.47g) were higher in both raw materials for the study (ALP and PWF). Likewise, the ash (2.37-17.97g) and protein (11.96-31.56g) were recorded as higher in the raw materials for the study. The micronutrient content of the raw materials showed that ALP had a higher nutritional composition than PWF with a statistically significant difference at $p < 0.05$. Mineral content

of calcium was (30.00-2600mg), magnesium (40-120mg), zinc (3.267-7.068mg), copper (1.00-17.34mg) manganese (1.434-3.00mg) and iron (7.200-24.00mg). The moisture of the ALP enriched *Ujeqe* prototypes was low, connoting a keeping quality of the shelf-life of the enriched ALP *Ujeqe* food products. All the macronutrient nutrients of ALP supplemented *Ujeqe* (Table 3) were enhanced with increased concentration of ALP. The enrichment was noted in the ash content of the 2% (2.2-0.0g), 4% (2.05-0.01g) and 6% prototypes (2.31-0.03g) respectively, with a statistically significant difference at $p < 0.05$. Likewise, levels of copper, phosphorus, calcium, zinc, manganese, and iron were recorded. All supplemented *Ujeqe* were enriched in nutrient content. The sensory evaluation indicated that all samples were acceptable. The 6% ALP *Ujeqe* prototype was the most enriched, but the 2% sample was the most acceptable prototype compared to the control sample followed by 4% and 6% respectively. There was no statistically significant difference in the overall consumer acceptability level of the enriched sample when compared with 0%, 2% and 4% ALP supplemented prototypes. The ALP supplemented *Ujeqe* was enhanced both in macro and micronutrients. The high ash content of the food samples in this study connotes ALP-supplemented sample richness in mineral content. The mineral content of the raw material, ALP was significantly higher than PWF, supplemented *Ujeqe* with 6% ALP containing the highest mineral content. Hence, from the nutritional point of view, the formulation was enriched significantly in some selected mineral content. Therefore, ALP supplementation in staple foods like *Ujeqe* can be a potential food-based approach that is cost-effective and a sustainable measure for addressing food and nutrition insecurity, especially among the malnourished population. Fibre was not analysed in this study. Thus, future studies can explore ALP-supplemented *Ujeqe's* fibre content and microbial tests can be carried out to determine its shelf stability. Continuous research around underutilised food plants including *Amaranthus* for food and nutrition security can be explored in other staple foods as viable measures to tackle nutrition security. Also, the need for effective implementation of relevant research to help in the domestication of *Amaranthus* cannot be overemphasised. Thus, improving the small-scale farming of *Amaranthus* to a larger scale appears to be a realistic way forward. Therefore, the South African government should assist small-scale farmers of *Amaranthus* with all the extension services needed as this may enhance their productivity and provide food and nutrition security for the community. Similarly, policymakers should consider the provision of land, finance, fertiliser, seeds, herbicides, fences, insecticides, and grants to encourage farmers to plant leafy vegetable foods like *Amaranthus* for nutrition security. Enhancing small-scale farmer's capital should involve financial support from the government and the provision of land.

PREFACE

The work described in this thesis was carried out in the discipline of Food Security, School of Agricultural, Earth and Environmental Sciences, at the University of KwaZulu-Natal, Republic of South Africa. This was undertaken within the March 2019 and February 2023 academic sessions, under the supervision of Prof. Kolanisi Unathi, Prof. Ngobese Nomali and Dr. Mayashree Chinsamy.

Signed: _ [redacted] Date: July 2023

Ruth Nachamada Olusanya (Candidate)

As supervisors of the candidate, we agree to the submission of this dissertation:

Signed: [redacted] Date: July 2023

Prof. Unathi Kolanisi (Supervisor)

Signed: [redacted] Date: -18/07/2023

Prof. Ngobese Nomali (Co-Supervisor)

[redacted] Date: July 2023

Dr Chinsamy Mayashree (Co-Supervisor)

DECLARATION

I, Ruth Nachamada Olusanya (215081315), declare that:

1. The research reported in this thesis except where otherwise indicated, is my original work.
2. This thesis, or any part of it, has not been submitted for any degree or examination at any other University.
3. Where other sources have been used, they have not been copied and have been acknowledged properly.
4. This dissertation does not contain text, graphics or tables copied and pasted from the internet, unless specifically acknowledged and the source being detailed in the dissertation and in the relevant reference section.

Signed: ____[redacted]__ Date: July 2023

Ruth Nachamada Olusanya (Candidate)

CHAPTER 1: INTRODUCTION

1.1 Background to the study

Malnutrition, especially micronutrient deficiency, is a food related public health challenge that has impacted negatively on the wellbeing of those in middle- and low-income countries (Vassilakou, 2021). The world's population is growing at an exponential rate; it is estimated to be over 8 billion people as reported by United Nations on November 15, 2022 (Oluwole et al., 2023). About 870 million people out of the eight billion population are unable to access sufficient food to optimise dietary needs. About 98% of this hungry population lives in the developing countries, where 15% of the population are undernourished, which implies a compromise in the food and nutrition security status of those people (Oluwole et al., 2023). Food insecurity is often linked with food and nutrition insecurity, with the former being the forerunner to the later challenges of the devastating impact of malnutrition in all its forms. Thus, those individuals that are food insecure are undernourished in terms of calories, but will also be deficient in more than one essential nutrient (Correia et al., 2017; Emmanuel and Babalola, 2022).

The absence of balanced diets is exhibited in various forms of malnutrition which encompass undernutrition and overnutrition and is known as the triple burden of malnutrition; the co-existence of undernutrition (shown by wasting and stunting), micronutrient deficiencies (often regarded as hidden hunger), and overnutrition (overweight and obesity) (Omachi et al., 2022). This challenge (malnutrition) has impacted more on the vulnerable population as is evident by the increased risks of deficiencies and chronic life-style diseases which include the non-communicable diseases (Olusanya et al., 2023). Several underlying causes of malnutrition in resourced and under-resourced countries, including South Africa, are associated with poverty as the leading cause. A high proportion of poverty has been reported in KwaZulu-Natal (KZN) (Govender et al., 2017; Omachi et al., 2022). An evaluation of food and nutrition insecurity of households in some selected rural communities in KZN, South Africa, showed that about 47% to 53% of black South Africans are disadvantaged (Govender et al., 2017). Consequently, it is reported that such households are at a high risk of malnutrition as they cannot afford a balanced diet (Omachi et al., 2022). In attempts to improve the food and nutrition security of poor rural household, several strategies such as biofortification and promotion of underutilised crops that are nutrient-dense have been proposed to improve dietary diversity and balanced diets (Ofori et al., 2022) However information regarding the supplementation of *Ujeqe* with underutilised indigenous the leafy vegetable *Amaranthus* is scarce and has not been reported.

An inadequate diet and persistence of calorie deficiency can expose an individual to nutrient deficiency diseases which are preventable with adequate and safe nutrition (Hickey and Unwin, 2020; Dukhi, 2020; Omachi et al., 2022). Food and nutrition insecurity has been defined as the absence of adequate nutrients, a significant challenge (malnutrition) that is ravaging many ppeople'slives, especially among the rural population of many developing countries (Drammeh et al., 2019). The most fundamental cause of all forms of malnutrition is inadequate nutrition resulting from the consumption of cheap and available alternative foods that are considered to be “full plate but empty” which are low in essential nutrients. Such foods are regarded as a compromised diet because they are often monotonous in preparation as they are mainly starch-based foods including root/tuber and cereal foods without fruits and vegetables. This type of diet has been identified as the root cause of all forms of malnutrition including micronutrient deficiency.

Although countries like South Africa (SA) are included among countries where the citizens are self-sufficient in terms of food at the national level, nevertheless accessing safe and nutritious food at the household level is a challenge (Emmanuel and Babalola, 2022; Wijaya et al., 2021). Food security and nutrition security are interdependent; unless this is understood and addressed at the household level, malnutrition will continue to be a serious global health challenge and is a top risk factor for increased burden of diseases (Ehrlich and Harte, 2015; Grote et al., 2021). Malnutrition, especially micronutrient malnutrition, is a wide-spread nutrient-related health problem that is associated with increased morbidity and mortality rate most evident among the vulnerable population (Isanaka et al., 2019). It has been reported that about 45% of deaths among children below the age of five are linked to undernutrition which is a form of malnutrition (Vassilakou, 2021). Inadequate intake of nutrients, especially the essential nutrients like vitamins A, and C, the B vitamins, iodine, folate, iron, and zinc, are identified as the most common deficiencies prevalent at pandemic levels in most developing countries (Gayer and Smith, 2015; Olusanya, 2018).

Measures to tackle the worst consequences of malnutrition (nutrient deficiency) and related health challenges through fortification of staple foods that target the larger population have been explored (Wijaya et al., 2021). However, the deficiency of essential nutrients still lingers among the marginalised. Due to the nutrient related diseases, current trends in change of people's dietary lifestyle for healthier food options is on the rise (Olusanya et al., 2020; Norman et al., 2021). People optimise their dietary needs with food supplements which are expensive for the common person to access. Food-based approaches that discourage monotony during food preparation and encourage a diversified dietary approach remains the most viable way forward in tackling malnutrition (Norman et al., 2021). Hence, there is increased concern and interest regarding research on accessible, cost-effective, sustainable, and results-oriented measures that can reduce vulnerability to food and nutrition insecurity thereby tackling malnutrition, especially micronutrient malnutrition.

The other side of the coin is that while some individuals have access to a variety of nutrient-dense food sources, there is an inability to make wise choices among the available indigenous plant-based ingredients, which include traditional vegetables like *Amaranthus* as components for enriching or innovating healthy food (Ngema et al., 2018). This challenge often exists because of negative attitudes, preferences, and misperceptions, linked to some indigenous leafy vegetable plants like *Amaranthus* as a food ingredient for nutrient enrichment. Unfortunately, such negligence has contributed to a decline in the cultivation, food processing, preservation, and novelty in the utilisation of indigenous leafy vegetable plant foods like *Amaranthus* in the staple diet (Achigan-Dako et al., 2014; Ambuko et al., 2017). Thus, a poor dietary lifestyle has evolved where people's diet is mostly characterised by cereal/starch-based foods, especially those loaded with concentrated refined sugars, high fats and sodium chloride coupled with sedentary lifestyle and limited exercise, which is a big challenge to human health (Arndt et al., 2020). Studies report that many people are exposed to micronutrient deficiency (also known as hidden hunger) and the overconsumption of food which impacts non-communicable diseases among the vulnerable group (Banerjee and Maitra, 2020; Béné, 2020). Curbing the prevalence of malnutrition among the vulnerable group requires exploration of cost-effective and sustainable measures for tackling all forms of malnutrition, especially micronutrient deficiencies.

Research indicates that one in four poor rural households in SA is food insecure, particularly in the winter period when foods prices tend to increase and the less privileged are unable to access nutritious food (Hendriks et al., 2016; Emmanuel and Babalola, 2022). Sadly, this trend of food insecurity has not decreased in recent years; rather it has been reported that about 16 million people in South Africa are considered food insecure, with most of the affected being those living in rural communities (Mabhaudhi et al., 2018; Emmanuel and Babalola, 2022). In the year 2019, the National Department for Health reported that 43% of children below the age of five years were considered malnourished, 27% experienced stunting, 3% with wasting, 13% were overweight, and about 68% of South African women were reported overweight (Emmanuel and Babalola, 2022). In Africa, including South Africa, the less privileged households have a limited variety of foods which consist of bulk starch staples with sugar and salt, with only a little relish of vegetables (Emmanuel and Babalola, 2022). Relying on staple foods (including cereal-based foods) known to have limited essential nutrients is the primary cause of all forms of malnutrition (Emmanuel and Babalola, 2022; Norman et al., 2021). Therefore, fruits and green leafy vegetables including *Amaranthus* should be included in the diet of both young and old persons; this may boost their immune system and provide food and nutrition security.

Since green leafy vegetables are a rich source of macronutrients and micronutrients, previous studies have maintained that food-related health challenges, especially all forms of malnutrition, can be curbed with increased consumption of an adequate diet that contains fruits and leafy vegetables like *Amaranthus* (Morris et al., 2018). Furthermore, the trends of traditional medicine are on the rise; it is reported that traditionally, healing potentials abound in many leafy vegetables especially *Amaranthus* which is identified as an underutilised crop. Pharmacologically, green leafy vegetables, including *Amaranthus,* are nutraceutical and phytochemically endowed to boost immunity (Emmanuel and Babalola, 2022). The active compounds in *Amaranthus* have been identified as a great destroyer of free radicals in humans, slow down the aging processes while alleviating food and insecurity and its hazardous consequences, and boost immunity (Kawade et al., 2013; Frugé et al., 2021). Globally and in South Africa the consumption of vegetables, especially the green leafy vegetables, is low (Sarkar et al., 2022; Zulu et al., 2022). Thus, this study aimed to investigate the nutritional potential of a multipurpose plant (*Amaranthus)* whose grains have been utilised as fortificants in various staple foods but whose leaves have been neglected, as an additive to the staple food *Ujeqe*.

Amaranthus is a C4 plant that grows like any other weeds. It is taxonomically difficult to classify them, however, diverse species of *Amaranthus* have been studied (Achigan-Dako et al., 2014; Emmanuel and Babalola, 2022). About 60-70 species of *Amaranthus* have been cultivated around the world with America being the historical origin of *Amaranthus. Amaranthus* has naturalised in sub-Saharan Africa and Asia (Emmanuel and Babalola, 2022), Gerrano et al., 2015). *Amaranthus* is considered as a pigweed and a pseudo-cereal crop that is in fact a multipurpose plant. It is one of the few cereal crops that provides both grains and edible leaves of high nutrient quality for humans and animal consumption and sustenance, besides their uses in religious worship (Ancient Grain, 2018). The grain of *Amaranthus* has been consumed by humans in many parts of the world and has been investigated to have a relatively high protein and healthy lipid content, and a lower starch content than those species grown primarily for grain purposes. The leaves have been used like other vegetables in soups and various dishes (Alegbejo, 2013; Alekhina et al., 2021). Despite the potential of *Amaranthus,* the crop is relegated to the background as it is associated with poor people, hence, it is underutilised.

Furthermore, the introduction of exotic collard vegetables has been a factor affecting people's preferences for traditional vegetables like *Amaranthus* (Achigan-Dako et al., 2014; Emmanuel and Babalola, 2022). In ancient times, *Amaranthus* was utilised as a food in many communities (Ancient Grain, 2018). However, the inability to constantly conserve indigenous knowledge systems, especially those of the wild varieties of food plants in many localities, has contributed to the neglect of or loss of many crops in places where they were once grown. Additionally, it appears that there is a lack of or limited knowledge of novel methods of the application of *Amaranthus* in indigenous foods including the fading away of the transfer of heritage to the younger generation which seems to be a big challenge among the factors that have led to *Amaranthus* being underutilised (Olusanya et al*.*, 2021). One of the reasons for this is that *Amaranthus* is often viewed as food for the less-privileged and as just a weed; such perceptions produce a negative attitude which reduces its utilisation in the regular diet of the younger generation (Achigan-Dako et al., 2014; Aderibigbe et al., 2022). Regardless of the wrong perceptions, *Amaranthus* remains a pillar in the diets of some rural and urban households although novelty is lacking in terms of food preparation.

Amaranthus grows on its own. Only a few species of *Amaranthus* are cultivated in developing countries of sub-Saharan Africa (SSA). Indigenous leafy vegetables like *Amaranthus* have been underutilised, being replaced by variety of introduced species of vegetables especially the cruciferous genus like kale, cabbage and mustard greens, to mention a few (Achigan-Dako et al., 2014; Aderibigbe et al., 2022). Not including vegetables in the staple food diet reduces the intake of essential nutrients which over time may impact negatively on well-being. Those susceptible to the impact of malnutrition are usually marginalised populations who are vulnerable to the devastating consequences of micronutrient deficiency challenges (Dukhi, 2020). This condition becomes more challenging if the exotic introduced vegetables that are preferred over *Amaranthus* are lower in nutritional value than *Amaranthus.*

Although vegetables like *Amaranthus* may be neglected or underutilised in many communities, several studies have found that *Amaranthus* offers exceptional opportunities to diversify the farming systems of smallholder farmers (Aderibigbe et al., 2022). Indigenous leafy vegetables such as *Amaranthus* have been established to possess essential nutrients that can optimise the food and nutrition security of individuals, and if grown for sale can increase household income and alleviate poverty (Emmanuel and Babalola, 2022). Furthermore, indigenous vegetables including *Amaranthus* form part of a cultural heritage, and the indigenous knowledge system must, therefore, be preserved and passed on to the next generation (Olusanya et al*.*, 2021).

Amaranthus has its origin in western, central and south America where these plants are well known for their grain-producing species, with limited species being grown for leafy vegetables (Achigan-Dako et al., 2014; Aderibigbe et al., 2022). Although the leafy vegetables are endowed with essential vitamins, minerals, and phytochemicals, *Amaranthus* leaves have scarcely been explored as enhancers in staple foods. To combat malnutrition and hidden hunger, the World Health Organization (WHO) emphasises the need for increased intake of green leafy vegetables, however, adherence is still low (Uusiku et al., 2010; WHO, 2020). South Africa has responded to this charge by initiating an Agricultural Research Council (ARC) that promotes the cultivation and utilisation of vegetables including underutilised vegetables like *Amaranthus* (Bvenura and Afolayan, 2015; Maseko et al., 2017). *Amaranthus* grain has been utilised to improve and enrich staple foods, but *Amaranthus* leaves have been underutilised in staple foods including *Ujeqe* bread which is a cereal-based food.

Bread is a staple food that provides nutrition to many individuals across the globe. The varieties of bread made in human history shows how much humans have tried to be creative in the industry of bread making (Carocho et al., 2020) However, there is a scarcity of information on *Amaranthus* leaf powder (ALP) supplemented *Ujeqe*.

Bread of all forms is a common food that is made in different forms and consumed in almost every continent of the globe (Gębski et al., 2019). *Ujeqe* is a form of traditional bread appreciated in South Africa, but, since it is a cereal-based food, it is considered limited in essential nutrients. Hence, in this study, *Ujeqe* is investigated as a medium to deliver essential nutrients to *Ujeqe* consumers. The ingredients for all types of bread including *Ujeqe,* comprise refined wheat flour, sugar, yeast, oil and water which are mixed into a dough that is either viscoelastic or cohesive (Pico et al., 2015; Huang and Miskelly, 2016; Khalifa et al., 2020). Bread like *Ujeqe* is appreciated because of the simplicity of the ingredients and its easy mode of preparation (Pico et al., 2015). Bread, including *Ujeqe,* is a convenience food that provides consumers with calories, but consuming bread alone provides limited exposure to essential nutrients (Tolve et al., 2021). Due to economic issues, cultural inclination, individual dispositions to food, personal preferences, and health issues including the lack/limited knowledge of nutrition, tubers like cassava and various cereals (rye, barley, maize, rice, sorghum, millet, oat, and wheat) have been utilised in different types of bread (Huang and Miskelly, 2016; Tolve et al., 2021). Currently, consumer preferences are changing towards healthier options of food. Therefore, bread can be modified to an enhance the product, because consumption of traditional *Ujeqe* bread types is appreciated in some ethnic group including the study area. Thus, this study uses a natural nutrient-dense food plant (*Amaranthus*) to enhance the nutritional content of *Ujeqe.* This study investigates the utilisation of *Amaranthus* leaf powder to supplement *Ujeqe* wheat flour for the alleviation of food and nutrition insecurity in Empangeni, South Africa.

1.2 Significance of the study

Ujeqe is a wheat-based indigenous food in South Africa; it is a staple food among the Zulu community, especially in Empangeni. It is commonly consumed by all age groups, excluding babies. *Ujeqe* is usually consumed along with protein rich foods like *Usu* (offal meat), beans and other meat dishes or stews. However, those who cannot access the protein rich complementary food consume it as a snack or a single meal. Unfortunately, consuming wheat-based food product alone does not supply the nutrients essential for wellbeing (Nuss and Tanumihardjo, 2010). In addition, plain wheat flour which is the basic ingredient in *Ujeqe* lacks some essential nutrients because the bran and germ are removed in the milling processes, leaving just the endosperm, which consists mainly of carbohydrates and a small amount of minerals and vitamins (Sarwar et al., 2013). Over reliance on inadequate food is considered as a key obstacle to economic growth and social progress, which are all crucial when pursing and achieving most of the sustainable development goals (SDGs). Hence, a comprehensive and sustainable approach is needed to tackle this problem. *Amaranthus* is a nutrient-dense plant that is climate friendly, is resistant to plant diseases, and requires little attention for its cultivation (Aderibigbe et al., 2022; Emmanuel and Babalola, 2022). Although *Amaranthus* is a medicinal plant, it has several nutritional potentials to be explored as supplement/fortifying agent for improved household nutrition. Globally and in South Africa malnutrition, including deficiencies, exist. Fortification of food with *Amaranthus* seeds has been investigated for tackling malnutrition (Peter and Gandhi, 2017; Qumbisa et al., 2020). However, the leaves which have great potential to optimise inadequacies in staple foods has been utilised in *Ujeqe*. Since *Amaranthus* is nutrient dense, this study investigated ALP in *Ujeqe* as it considered as a viable, cost-effective, and sustainable measure for improved nutrition security (Achigan-Dako et al., 2014; Aderibigbe et al., 2022). Also, this study will create awareness regarding ALP nutritious *Ujeqe.*

1.3 Problem statement

Malnutrition, including micronutrient deficiency (called hidden hunger) is a nutrient-related challenge that results from a compromised diet of starchy and cereal-based foods which results in an inadequate intake of essential nutrients (Bain et al., 2013; Egbi et al., 2020). More than 30% of the world's population suffers from nutrient-related deficiency morbidity and mortality rates (Aderibigbe et al., 2022). The world's population is growing at an exponential rate and was estimated to be over 8 billion inhabitants as reported by United Nations on November 15, 2022 (Oluwole et al., 2023). About 870 million people out of the eight billion population are unable to access sufficient food to optimise their dietary needs with about 98% of this population living in the developing countries, where almost 15% of the population is undernourished (Oluwole et al., 2023). There is a link between food insecurity food and nutrition insecurity, with the former being a forerunner to the later challenges of the devastating impact of malnutrition of all forms.

A food-based approach remains a cost-effective and sustainable measure for tackling malnutrition. The issues surrounding the impact and aftermath of Covid-19 cannot be underestimated.

Challenges to food access are a factor for individuals whose diet is being compromised by starch and cereal-based foods, which are limited or lacking in essential nutrients that are required for the functioning of the system (Aderibigbe et al., 2022). Similarly, the sudden rise in the cost of living is an added challenge to acquisition of nutritious food. (Béné, 2020). Limited purchasing power, personal/household preferences, and attitudes are identified as contributory factors to the underutilisation of *Amaranthus* (Qumbisa et al., 2020; Aderibigbe et al., 2022). Thus, available nutrient-dense food plant materials such as leafy vegetables are proposed to address food and nutrition insecurity, especially among the less privileged and rural communities like those in Empangeni, South Africa.

Many indigenous food materials like *Amaranthus* are endowed with essential nutrients to address malnutrition. The seeds are utilised to enrich staple foods; however, the leaves are underutilised and under-consumed globally and in Africa, They have not been explored to their maximum potential to tackle malnutrition (Achigan-Dako et al., 2014; Aderibigbe et al., 2022). Information regarding the processing ALP and its utilisation in wheat food products, including *Ujeqe*, is scarce. Hence, the study investigate ALP in *Ujeqe* wheat flour for addressing food and nutrition insecurity in Empangeni South Africa.

1.4 Aim of the study

This study aimed to use *Amaranthus dubius* leaf powder as an ingredient to develop ALP-supplemented wheat flour to make *Ujeqe* for the alleviation of food and nutrition insecurity in the rural community Empangeni in northern KwaZulu-Natal province, Republic of South Africa.

1.5 Specific objectives

1. To review the *Amaranthus* nutraceutical position, potentials, and uses of Amaranthus in America, Asia, and Africa.
2. To identify the various species (varieties) of *Amaranthus* commonly sold in the formal and informal markets and investigate the dynamics of *Amaranthus* in urban and rural value chains in the KwaZulu-Natal province of South Africa.
3. To assess the utilisation of *Ujeqe* and *Amaranthus* in the study area.
4. To develop ALP-supplemented and analyse the proximate and mineral content of the control and ALP-supplemented *Ujeqe* samples.
5. To conduct sensory evaluation and evaluate the consumer acceptability level of the ALP-supplemented *Ujeqe* food samples.

1.6 Research questions

1. What is the nutraceutical position, potentials, and uses of *Amaranthus* in America, Asia, and Africa?
2. What are the various species (varieties) of *Amaranthus* commonly sold in the formal and informal market and what are the dynamics of Amaranthus in urban and rural value chains in the KwaZulu-Natal province of South Africa?
3. What is the utilisation level of *Ujeqe* and *Amaranthus* in the study area?

4. Can *Amaranthus Ujeqe* be developed using *Amaranthus* leaf powder as an ingredient for supplemented wheat flour *Ujeqe*? What is the nutritional composition, especially the mineral content, of ALP supplemented *Ujeqe*?
5. What is the consumer acceptability level of *Amaranthus* leaf powder supplemented plain wheat flour *Ujeqe*.

1.7 Definition of terms

ALP: *Amaranthus* leaf powder

- **Food security: -** refers to a condition where everyone always has the physical, social, and monetary power to acquire food that is safe, sufficient, and nourishing to meet the choices and dietary needs of people for livelihood and good health without resorting to some measures of getting food through stealing, scavenging and other illegal sources to survive.
- **Food access: -** is the physical and monetary empowered ability by all categories of people, including full-time, part-time, and smallholder farmers, to choose and purchase food of their choice with ease.
- **Micronutrient:** Micronutrient is the term used for useful food nutrient elements such as vitamins and minerals which are needed in small amounts by the body. These help to sustain the body's functioning and maintenance of energy levels, metabolism, cellular function, and physical and mental well-being (WFP and UNICEF, 2022).
- **Malnutrition:** A broad term that describes the concept of micronutrient deficiency and over ingestion of calories. To be malnourished means the diet lacks adequate calories, good protein, and other essential nutrients for growth and maintenance. The inability to benefit maximumly from the nutrients ingested results in undernutrition of various essential nutrients. Individuals can also be malnourished if they consume too many calories. Thus, malnutrition results from either insufficient nutrition, absence or limited essential nutrients in the food ingested, or if there is a challenge to the body's ability to absorb or utilise the nutrients obtained from the food ingested.
- **Supplement:** A substance to optimise an individual's diet and is taken in the form of capsules, tablets, syrup, liquid forms, or powder forms. They can be obtained from food materials or be made synthetically to improve the degree of its intake. Supplements are intended to complement a diet and increase nutrients that may be missing or inadequate in one's food plate.
- **PWF:** Plain wheat flour

- ***Usu:*** An offal meat
- ***Ujeqe*:** A traditional steamed bread made from plain wheat flour.
- **Undernutrition:** This is a form of malnutrition that results from eating insufficient essential nutrients, or due to an abnormality in absorbing the nutrient ingested. This is not equal to under-eating because it can also occur even when one over-eats.

1.8 A brief outline and organisation of the thesis

Chapter 1 of this thesis describes the introduction and background to the study with information on the prevalence of malnutrition, including the concept of essential nutrient deficiency. Chapter 2 of the study provides a review of the literature with a global overview of the underutilisation versus nutraceutical potentials of *Amaranthus* to combat food and nutrition insecurity and all forms of malnutrition, including micronutrient challenges in sub-Saharan Africa (SSA) and South Africa. Chapter 3 describes the methodology and the conceptual framework of the study. Chapter 4 describes the dynamics of the *Amaranthus* urban and rural value chain in KwaZulu-Natal province, South Africa. Chapter 5 reports the results of a survey study on the utilisation of *Ujeqe* (steamed bread) and *Amaranthus* leaves for improved food and nutrition security. In the same chapter, the knowledge and attitudes of participants regarding *Amaranthus* as a potential supplement in *Ujeqe* food products is presented. Chapter 6 describes the mineral composition and consumer acceptability of *Amaranthus* leaf powder-supplemented wheat flour *Ujeqe* for improved nutrition security. ALP-supplemented *Ujeqe* food samples were developed and analysed for mineral composition. Also, in Chapter 6, consumer acceptability of ALP-supplemented *Ujeqe* is assessed. Chapter 7 presents the summary, conclusion, future research, and study recommendations. Appendices A to F are presented at the end of this study.

1.9 Referencing style

The referencing style used in this thesis is according to the guidelines used in the Discipline of Food Security, University of KwaZulu-Natal, Pietermaritzburg.

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CHAPTER 2: REVIEW OF LITERATURE

Underutilization Versus Nutritional-Nutraceutical Potential of the *Amaranthus Food* Plant: A Mini-Review

Research chapter Published in Applied Science MDPI

(https://doi.org/10.3390/app11156879**)**

Abstract

Amaranthus is a C4 plant tolerant to drought, and plant diseases and a suitable option for climate change. This plant could form part of every region's cultural heritage and can be transferred to the next generation. Moreover, *Amaranthus is* a multipurpose plant that has been identified as a traditional edible vegetable endowed with nutritional value, besides its fodder, medicinal, nutraceutical, industrial, and ornamental potentials. In recent decade *Amaranthus has* received increased research interest. Despite its endowment, there is a dearth of awareness of its numerous potential benefits hence, it is being underutilized. Suitable cultivation systems, innovative processing, and value-adding techniques to promote its utilization are scarce. However, a food-based approach has been suggested as a sustainable measure that tackles food-related problem, especially in harsh weather. Thus, in this review, a literature search for updated progress and potential uses of *Amaranthus from* online databases of peer-reviewed articles and books was conducted. In addition, the nomenclature, nutritional, and nutraceutical value, was reviewed. The species of focus highlighted in the review include, A. *blitum,* A. *caudatus*, A. *cruentus*, A. *dubius,* A. *hypochondriacus,* A. *spinosus*, A. *thunbergii*, A. *tricolor,* and A. *viridis.*

Keywords: *Amaranthus;* nutraceutical; nutrition security; potentials; traditional uses; underutilized vegetables

2.1 Introduction

There is great pressure on the agricultural sector to produce 70% of food that would feed the 40% projected population increase of nine billion people worldwide by the year 2050 (Aswal et al., 2016). Achieving such projections is a concern in research and, it calls for constant exploration of underutilized edible crops to pro-vide food security for the world population. Additionally, the burden of hidden hunger has been linked with malnutrition, a food-related challenge. Infant, young children, young women of the age-bearing group in the middle- and low-income countries are at risk of the devastating effects, that impair vision, intellect, and retarded development as well as inflicting morbidity that limits livelihood of per-sons, especially the smallholder farmers in rural areas (Aswal et al., 2016; Aderibigbe et al., 2020). Interestingly, varieties of food plants that are drought tolerant like Amaranthus have been reported to have massive potential of curbing food-related problems, like micro-nutrient deficiencies challenge. Their contribution to food and nutrition security and consequential benefits that aimed at the improving wellbeing and livelihood is worth exploring. It is reported that about 30,000 plant species around the world are edible, with only 7000 that have been utilized as food (Ramdwar, Chadee and Stoute, 2017). Interestingly, many of these underutilized food plants grow naturally in many fallow landscapes, but people harvesting them are the most disadvantaged in the rural community of many developing countries. Since the Amaranthus plant grows commonly, the indebt awareness of its potential and uses are limited. Little wonder most of the food crops, including Amaranthus, are underutilized. Amaranthus is a traditional crop with its origin traced to America, where it has been cultivated between 6000 - 8000 years ago, but currently, Amaranthus is cultivated across the globe (Achigan-Dako, Sogbohossou and Maundu, 2014). Therefore, Amaranthus h

as been rediscovered among the few edible crops with a multipurpose potential that can be worth exploring. This is because of its diversified usefulness in industry. It has provided aesthetic value, with edible grains, leafy vegetables, fodder, and dietary sources compared to the most predominant staple crops (Achigan-Dako, Sogbohossou and Maundu, 2014; Ramdwar, Chadee and Stoute, 2017; Aderibigbe et al., 2020). Notwithstanding the geographical location of Amaranthus spp. It is recognized as a plant that grows within a short period (Achigan-Dako, Sogbohossou and Maundu, 2014). However, there is a challenge in recognizing and classifying the species of Amaranthus, this is due to the critical morphological similarities, phenotypic variability, and crossbreeding that causes nomenclature disorders (Iaimonico, 2016; Wolosik and Markowska, 2019; Aderibigbe et al., 2020). However, about 60–75 species of Amaranthus exist across the globe, 10 of which are dioecious (implying that, the male flowers are on one plant and the female flowers are on another plant), native to North America. While the remaining are monoecious (both male and female flowers are found on a single individual plant). The latter species are widespread across the different continents, from tropical lowlands to the Himalayas (Noori, Talebi and Nasiri, 2015). In the Aztec pre-colonial period, Amaranthus was a significant plant, as it was central in the worship of gods. It is also used as a medicinal plant, a source of dye, fodder, and an ornamental plant, in addition to its, use as a staple food in places where they have been cultivated (Randhawa et al., 2015). It is reported that Amaranthus has adapted to the sub-Saharan African region, such that it is a plant that grows even along roadsides and is also seen growing on many fallow landscapes (Qumbisa, Ngobese, and Kolanisi, 2020). In South Africa, for example, Amaran-thus is one of the most common indigenous leafy vegetables, which grows well in the summer season. To be precise, Amaranthus is found in places like Kwazulu-Natal, Northwest, Limpopo, and Mpumalanga, the homeland provinces of Amaranthus, where it is grown massively (Qumbisa, Ngobese, and Kolanisi, 2020) Amaranthus *thunbergii,* A. greazicans, A. *spinosus,* A.deflexus, A. *hypochondriacus,* A. *viridis,* and A. *hybridus* are the most predominant species. Amaranthus being a C4 plant, the species are all tolerant to adverse climatic conditions even, in prolonged dry periods (Maseko et al., 2017). Although, Amaranthus is rarely cultivated when compared to other African leafy vegetables (Maseko et al., 2017). In countries where Amaranthus is grown, various Amaranthus colours exist, ranging from gold, red, and green to purple (Aswal et al., 2016). The majority of Amaranthus species have edible seeds and leaves, with some species known as vegetable amaranths, which include: A. *blitum*, A. *lividus,* A. viridis, A. *gracilis* Desf. and A. *tricolor*, which is synonymous with A. *tristis* L, A. *gangeticus* L (Topwal, 2019). Several studies on the grain Amaranthus have been conducted while Amaranthus leafy vegetables are being relegated in research resulting in limited information on the potentials of the leafy vegetable of Amaran-thus compared to the grain Amaranthus (Grobelnik Mlakar et al., 2009; Alemayehu, Bendevis and Jacobsen, 2015). Amaranthus seeds are edible just as other cereals usually, it is commonly known as pseudo-cereal (Achigan-Dako, Sogbohossou and Maundu, 2014). Several studies reported that Amaranthus seeds are a good source of gluten-free protein, which has been explored for making a variety of snacks across the world (Department of Agriculture, Forestry and Fisheries, 2010; Tömösközi et al., 2011). Amaranthus leaves have been used as greens, just like spinach. Also, it has been used as seasonings, just like mint being used in food. It has also been used in salads. Similarly, Amaranthus can be stewed with other vegetables like onions, garlic, tomatoes, they are sometimes used as dish like pepper pot (Ramdwar, Chadee and Stoute, 2017). Just as other vegetables are preserved, the leaves of Amaranthus ‘shelf-life can be extended by drying and milling it into powder and can be used for sauces preparation, which might improve its utilization even when not in the season (Jane, 2012; Aderibigbe et al., 2020; Qumbisa, Ngobese and Kolanisi, 2020). Processing of Amaranthus leaves into leaf powder, as a preservative measure, especially in South Africa, has been overlooked and thus, further contributing to it, being underutilized especially when it is out of season. On the other hand, it is reported that about ten species of Amaranthus are being considered troublesome weeds (Küpper et al., 2018). Despite people's perceptions, Amaranthus has received a resurgence in recent decades. Consistent studies show that Amaranthus is a multipurpose plant because the grains, stem, and leaves are edible, and the leaves could be utilized to enhance convenience food of low nutritional quality, especially instant noodles (Qumbisa, Ngobese and Kolanisi, 2020). Furthermore, Amaranthus can be explored as a smart food for tackling malnutrition challenges especially the scourge hidden hunger. Even-though Amaranthus have been grown across most of the continents of the world, there is still a scarcity of holistic information on the great potential of Amaranthus, especially of the leafy variety (Achigan-Dako, Sogbohossou and Maundu, 2014). Amaranthus species are tropical climates plants. They can thrive well without pesticides and fertilizers since it belongs to the C4, dicotyledonous group of herbaceous plants (Alemayehu, Bendevis, and Jacobsen, 2015). The C4 plants have been known to use a specific type of photosynthesis mechanism known as (C4 photosynthesis) this is to avoid photorespiration, which helps the plants to grow better in hot, dry environments; photorespiration is a condition where plants close their stomata to conserve water (Ramdwar, Chadee and Stoute, 2017). This means as the stomata closes, the carbon dioxide levels in the interior of the leaf fall, and the oxygen levels rise (Khanam and Oba, 2013). The C4 plants have been identified to grow well under temperatures above 25 °C during the day, and at night the temperature must not be lower than 15 °C. The C4 plants have demonstrated the ability to survive with little attention. Bright light and adequate availability of nutrients can be beneficial for maximum yields (Maseko et al., 2017).

Amaranthus has also been considered a superfood. Hence it is a promising and unique plant to be explored for its great intrinsic, essential nutrients since they are rich sources of micro-nutrients (essential vitamins and minerals), which have been studied as inevitable to optimum well-being. It is endowed with several compounds, including amino acids: lysine, arginine, histidine, leucine, cysteine, phenylalanine, isoleucine, valine, threonine, and methionine (Reyad-ul-Ferdous et al., 2015). Two broad groups of Amaranthus exist the grain and leafy Amaranthus. Although the leaves of the grain Amaranthus group are also consumed however, in places like Asia, the Amaranthus plant is specifically grown for its grain purposes. In addition, Amaranthus that is specifically grown for leafy purposes is subdivided into two species: A.tricolor and A.lividus, which are both equally called Amaranthus and are endowed with medicinal and nutraceutical properties (Girish, Dhan and Charu, 2014). It is reported that the phytochemical extract from leaves of Amaranthus spp., such as A.viridis has biologically active components (Qumbisa, et al, 2020). These active components include tannins, saponins, phenols, flavonoids, cardiac glycoside, steroid, and triterpenoids (Reyad-ul-Ferdous et al., 2015). Likewise, A. *viridis* possesses some chemical constituents that exhibit potent activities like anti-inflammatory, antihepatotoxic, antiulcer antiallergic, and antiviral actions (Reyad-ul-Ferdous et al., 2015). For example, A. *viridis* has been used in places like India and Nepal in traditional medicine to reduce labour pain and to act as an antipyretic, which reduces fever (Reyad-ul-Ferdous et al., 2015). Similarly, in Spain, specifically the Negritos of the Philippines, used Amaranthus leaves directly on skin diseases to cure eczema, psoriasis, and rashes. It has also been used as an anti-inflammatory agent of the urinary tract, venereal disease vermifuge, an-ti-rheumatic, antiulcer, analgesic, antiemetic, laxative, it improves appetite, is an antileprotic, treatment of respiratory and eye problems, treatment of asthma (Reyad-ul-Ferdous et al., 2015). Moreover, Amaranthus leaves are an important source of traditional medicine besides their use as a source of nutrition for humans and forage purposes.

Although Amaranthus possesses many medicinal and nutraceutical potentials, it is a crop that has suffered neglect, which perhaps led to its being stigmatized as a poor person's food plant (Achigan-Dako, Sogbohossou and Maundu, 2014). Amaranthus is perceived among the youth and urban population as a food plant for the poor (Maseko et al., 2017). However, on the contrary, among the wealthy, it is gaining interest and has been rediscovered as an important traditional leafy vegetable with several protective and curative properties, which are attributed majorly to the strong antioxidant and phytochemical properties (Njonje, 2015; Peter and Gandhi, 2017). Similarly, the systems of Amaranthus cultivation, processing, and value-adding techniques that could promote its utilization are now receiving research interest.

Currently, there is a trend in which people are health conscious of their diet, as health challenges are on the rise as well as taking in of food supplements, healthy foods, including calciferous vegetables, are being preferred (Perez-Rea and Antezana-Gomez, 2018). However, these supplements and healthy vegetables are expensive and are not accessible to the less privileged. Even though a variety of food plants, including Amaranthus, has been identified to supply most of the dietary needs, but more so, they are seen as cost-effective and sustainable food (Randhawa et al., 2015; Pettifor, Thandrayen and Thacher, 2018). Lack of sufficient information on its potential has limited its optimal utilization and maximum health benefits of Amaranthus. Such a dilemma is the drive for the interest in reresearchn the potentials of traditional leafy vegetables like Amaranthus. Hence a comprehensive review of the nutritional composition and potentials of leafy vegetables, such as Amaranthus, is important, which is the focus of this study.

While the calciferous vegetables (cabbage, kale, cauliflower, broccoli, lettuce, spinach, asparagus, cilantro celery) are quite famous and may be preferred, Amaranthus popularity has received a resurgence, and it is currently considered among the superfoods with numerous health benefits.

2.2 An Overview Background of *Amaranthus*

Amaranthaceae is the family name for all Amaranth, a genus Amaranthus spp. (Achigan-Dako, Sogbohossou and Maundu, 2014; Peter and Gandhi, 2017). Amaranthus emanates from an ancient Greek word connoting (flower), meaning eternal or not wilting, unfading, or life everlasting (Rastogi and Shukla, 2013; Reyad-ul-Ferdous et al., 2015). Amaranthus belongs to a sub-family of *Amaranthoideae* (Alercia, 2013; Peter and Gandhi, 2017). Its domestication dates to the 6th century BC, among Aesop's fables, who described Amaranthus as a short-lived flowering plant, having everlasting beauty when compared to roses. Phenotypically, Amaranthus has an attractively arranged inflorescence, a flowering plant that grows naturally or cultivated easily around home gardens. Research shows that about 60 to 75 species of Amaranthus with the family of *Amaranthaceae* are dispersed throughout the world, with only a few that are cultivated, and it originates from the temperate, subtropical, and tropical climate zones (Rastogi and Shukla, 2013; Topwal, 2019). Amaranthus' real origin is traced to America, where it is recognized as an immortal, a staple crop in the Aztec, Mayan, during the Incan civilizations (Peter and Gandhi, 2017). Currently, Amaranthus has spread widely across the globe. It is cultivated and consumed throughout India, Nepal, China, Indonesia, Malaysia, the Philippines, the whole of Central America, Mexico, and Africa (Peter and Gandhi, 2017). Among the grain types, some species are considered native to South and Central America, while other types are native to Europe, Asia, Africa, and Australia (Rastogi and Shukla, 2013; Topwal, 2019).

In Western, Central, and South America, Amaranthus are mostly recognized for their grain-purpose species. But there are cultivars grown for their leafy purposes. The leafy vegetable Amaranthus includes A. *tricolor,* A. *lividus,* A. *dubius,* A. *blitum,* and A. *hybridus,* which are crops of Africa, Southeast Asian, and Central American origin (Tubene and Myers, 2008). Amaranthus was cultivated by the mighty Aztecs 6000–8000 years ago in central Mexico, where it was not only a staple food for the Aztecs, though it played a vital role in the Aztecs' worship of gods and the Aztec human sacrifice rituals (Achigan-Dako, Sogbohossou and Maundu, 2014; Randhawa et al., 2015). During the Aztecs period, statues of their gods were built from the mixture of Amaranthus grain and honey. After the worship of the gods, the status is broken and is distributed to people for eating. Hence, the practice retard Amaranthus as a staple food (AncientGrains, 2018). This happened on the arrival of the Spanish with Cortez, as Christianity was being forced on the Pegan natives. Thus, the grain was banned, and the fields were burned, forbidden, cultivators or possessors of Amaranthus were severely punished. However, they were unable to destroy and eradicate the grain (Ancient Grains, 2018). Despite Amaranthus ‘rough history, little amounts of its grains managed to survive in a few remote areas, where the survived grains were primarily used for making traditional sweet called Alegria (AncientGrains, 2018). Amaranthus is currently grown in other parts of the world with few locations in the United States, Asia, and across Africa. Evidence of the cultivation of Amaranthus seeds emanates from the Coxcatlan cave in the Tehuacán Valley of Mexico, traced early to 4000 BC. Thereafter, evidence, such as burned and black Amaranthus seeds, was found throughout the US Southwest and the Hopewell culture of the US Midwest. Then, the Amaranthus grain was re-introduced in the United States in the 1970s (AncientGrains, 2018). Long after 300 years of it, being a less important crop, Amaranthus was rediscovered in Mexico, where it was shared on a ceremonial day with the descendants of the Aztecs, who believed that Amaranthus provided them with supernatural power in their religious practices. Even though Amaranthus is regarded as a neglected/lost crop (Cernansky, 2015), Amaranthus is well-known in many rural and urban communities because it is utilized at the household level; however, the mode of consumption differs by ethnic group. Although, Amaranthus appears to be a lost crop to many researchers and policymakers across the world, however, in localities where they have been cultivated and are appreciated, Amaranthus have provided humans with food. Nevertheless, updated information on their potentials and uses is needed as this can be informative and contribute to providing solutions to the world’s threatening problems of food insecurity and malnutrition challenges.

2.3 *Amaranthus a* Food Solution for Food and Nutrition Insecurity

There has been global progress in reducing nutrient-related challenges, especially in developing countries (Bouis and Islam, 2011). However, the difficulties that seem to hinder this achievement still include hunger, climate change malnutrition, including rural poverty, and lack of nutrition education, which affects the nutrition security of many populations, as many are unable to make wise choices of the available nutrient-dense food ingredient option that can enhance the inadequacies in most staple crops (Muthayya et al., 2013). Vegetables, including Amaranthus, have been identified as active ingredients that can contribute to the food supply of human essential dietary needs that can tackle hidden hunger issues. Although varieties of exotic vegetables like kale and collard greens, linked with high status, have been investigated as food solutions to nutrition security, they are inaccessible to the common man. Across the literature, Amaranthus is often linked with poverty. Hence, people do not want to be identified with poverty even though they may be poor (Achigan-Dako, Sogbohossou and Maundu, 2014). Such individuals lack the education that traditional vegetables, including Amaranthus variety, are being promoted as a promising plant with essential minerals and vitamins, nutraceutical, and phytochemicals properties (Cernansky, 2015; Ramdwar, Chadee and Stoute, 2017). Though the exotic vegetables appear to provide a sustainable measure for improving global food availability and food and nutrition security, little attention is shown to vegetables that are considered "lost crops", including Amaranthus (National Research Council, 2006).

Generally, several agricultural researchers and nutritional experts argue that vegetables, including Amaranthus, are endowed with essential nutrients yet to be exploited. For example, Amaranthus is currently ascribed worth as a superfood. Therefore, exploring traditional varieties of vegetables like Amaranthus for food and nutrition security cannot be overemphasized because, the nutritional needs of humans could be met via its inclusion in staple foods, which is a cheaper solution to preventable food-related health challenges incapacitating the human potentials.

It is believed that Amaranthus is not a true cereal, like wheat, sorghum, millet, maize, or barley, but, somewhat, it is considered as "pseudo-cereal" like the buckwheat crop (Grobelnik Mlakar et al., 2009; Achigan-Dako, Sogbohossou and Maundu, 2014).

Pseudo-cereal is one of the non-grass plant's crops that have been used, like any other true cereals belonging to the grass family. Hence, Amaranthus seeds can be grounded into flour and can be used in baking varieties of food products, especially snacks. Although Amaranthus are commonly known as pigweed, it is a unique plant that grows on its own. Hence, they are broadly cultivated world-wide for many reasons of interest, including industrial, medicinal, ornamental, fodder, and nutrition purposes. Amaranthus is considered a multipurpose plant since it has proved its worth in supplying cereal grains and leafy vegetables of high essential nutritional value for animals and human nutrition.

The essential nutrients found in Amaranthus include protein, calcium, iron, vitamins A, C, and K, riboflavin (B2), niacin (B3), vitamin B6, and folate (B9). Several studies attest that Amaranthus benefits are enormous and undeniable. Therefore, a regular diet plan can help combat nutrient-related health issues; mal-nutrition and especially micronutrient deficiency challenges (Rastogi and Shukla, 2013; Assad et al., 2017; Qumbisa, Ngobese and Kolanisi, 2020).

However, Amaranthus is a common crop that has been given little attention in research, though it is identified as a promising plant capable of combating most of the human nutrient deficiency challenges. Interestingly, Amaranthus supplies nutraceutical and phytochemical properties and other dietary needs of humans, though Amaranthus has been identified as low in calories, which can be a good option for weight loss. Amaranthus, being one of the superfoods plants, the leaves have been accessible in fresh form, but the powdered form of it is still scarce. This implies that the processing aspect of Amaranthus leaves into a new form or product, such as powder, is lacking or still at a low level. Although researchers still recommend the powder as having great potentials and are cost-effective, sustainable for alleviating hunger, but it is also vital for food and nutrition insecurity problem, especially among the vulnerable group because it could be used when it is out of season (Drzewiecki, 2001). Although Amaranthus is drought-tolerant, nutrient-dense, studies attest that it is fizzling out in some regions of the world where it was domesticated hence, making it an under-explored plant. Moreover, while malnutrition is still staggering, it continues to impact the burden of diseases and mortality on the vulnerable within the population of many developing countries, including sub-Saharan African countries. Hence, more interest in research around Amaranthus is needed to explore its potential and uses as viable solutions to food and nutrition insecurity. In addition, a novel medium of its delivery of the nutritional potential could be done via its inclusion of any of the Amaranthus species into most of the staple foods.

2.4 Common Species of *Amaranthus* Grown for Grain and Leaves and their Uses

Botanically, Amaranths species are not true cereals, like wheat and rice. However, they belong to the pseudo-cereals class. They are grown in many regions of the world for their edible leaves and seeds as the two main categories (Aderibigbe et al., 2020). Primarily, the three species of Amaranthus grown across the globe for grains include A. *cruentus*, A. *caudatus*, and A. *hypochondriacus*. Conversely, this does not mean their leaves and stems are not consumed. They are consumed when they are still at a tender stage. A. *cruentus* has been reckoned among crops with a high protein content that contains essential amino acids, including methionine and cysteine (Martínez-Núñez et al., 2019; Aderibigbe et al., 2020). The flour of the seed has been added to other cereals for making healthy snacks and complementary foods (Aderibigbe et al., 2020; Qumbisa, Ngobese and Kolanisi, 2020). Amaranthus sleaves can easily be prepared and consumed as a vegetable dish or as an ingredient in a sauce (Aderibigbe et al., 2020). The tender stems and leaves can be steamed or stir-fried and served as a side dish. It can also be cooked with assorted meats and fish in various oil, such as groundnut and palm oil (Aderibigbe et al., 2020). Consumption of Amaranthus differs from the localities where they are grown. It is usually not consumed alone, but it is also served as an accompanying dish. From the literature, there is no clear separation between vegetable and grain species. The reason is, the tender leaves of the grain varieties are equally utilized as the leafy Amaranthus (Aderibigbe et al., 2020). In Eastern and West Africa, for example, in Nigeria precisely, Amaranthus is a common vegetable that complements most carbohydrate dishes, such as pounded yam, amala, *tuwo*, and fufu. It is also recommended to boost one's red blood count (Akin-Idowu et al., 2013; Akin-Idowu et al., 2016). The popular leafy Amaranthus, include A. *cruentus*, A. *dubius*, A. *blitum*, and A. *tricolor*, A. *cruentus* has been cultivated both as a vegetable, fodder, medicine, and grain depending on the targeted market of the producer (Aderibigbe et al., 2020).

Different Amaranthus species (used as leafy vegetables, grains, ornamental and medicinal purposes) that are unique to some regions of the world have been identified. For instance, Figures 1–2 below describe Amaranthus, species, status, and their uses. Figure 1 A. describes Amaranthus *dubius* or wild spinach with palatable flavours hence, they are consumed as leafy vegetables foods for human and animals and are used for medicinal purposes (1B) Amaranthus *viridis*, are cultivated as leafy vegetables and for medicinal purposes. Even though Amaranthus *viridis,* are wild, they are occasionally cultivated as leafy vegetables, fodder, and for medicinal purposes (Achigan-Dako, Sogbohossou and Maundu, 2014). Figure 2. A–C describes common species of wild leafy Amaranthus varieties of A. *spinosus*, used as leafy vegetables for fodder and medicinal purposes. Amaranthus classification is described in Table 1, while the common names for Amaranthus in different countries are shown in Table 2. The vegetable Amaranthus are easily known by their inflorescence features, mostly axillary glomerulus, or short spikes. The flower originates from the bud of the leaf axil, three tepal lobes, three stamens, brownish-black seed with an indeterminate kind of growth (Achigan-Dako, Sogbohossou and Maundu, 2014). The grain Amaranthus are categorized by apical large to moderately large complex inflorescence containing aggregates of five stamens, cymes, five tepal lobes, seed with variable seed colour, and well-defined flange utricle *circumscissile* (Achigan-Dako, Sogbohossou and Maundu, 2014). Furthermore, grain Amaranthus is characterized by having discoid grains with a well-differentiated folded flange region and seed coat color other than black or brownish. However, some of the weedy Amaranthus that are cultivated can be used as vegetables. The weeds species are similar in their morpho-logical attributes with the leafy vegetable form, compared to the grain Amaranthus. Seed character is vital in differentiating the vegetable, grain, and weed Amaranthus (Achigan-Dako, Sogbohossou and Maundu, 2014).

Figure 2-1: (A) *Amaranthus dubius* or wild spinach (B)*Amaranthus viridis*

Figure 2-2: (A-C) Variant of *Amaranthus spinosus*

Table 2-1: Classification and description of *Amaranthus* [4,40]

Vegetable *Amaranthus*	**Grain *Amaranthus***	***Weed Amaranthus***
Amaranthus tricolor	*Amaranthus cruentus*	*Amaranthus spinosus* *Amaranthus hybridus*
var.*tricolor*	*Amaranthus hypochondriacus,*	*Amaranthus viridis,*
Amaranthus tricolorvor. Tristis	*Amaranthus caudatus*	*Amaranthus retroflexus*
		Amaranthus graecizans
		Amaranthus dubius

There are no clear differences between vegetable and grain species of *Amaranthus*. This is because the leaves of young grain varieties are also used as pot herbs sauce. Aside from the wild (*A.spinosus*) described in Figure 2,which grows voluntarily in fallow landscapes, four popularly cultivated species of vegetable *Amaranthus* exist: which include: *A.cruentus, A.dubius,A.blitum,* and *A.tricolor.* However, it is was identified that *A.cruentus* can be cultivated both as a vegetable and as grain, depending on the target market of the producer.(Aderibigbe *et al.*, 2020). This occurs because the weeds species show morphological commonality with leafy vegetable form, other grain forms of *Amaranthus*. The seed character is very useful in differentiating vegetables, grain, and weed *Amaranthus*. This because the vegetable group shares a striking similarity with the weed group in having brownish-black or black seeds.

Table 2-2: Common names of Amaranth in different countries around the world

Number	Language	Vernacular Name	Author
1–5	South Africa: Afrikaans	Hanekam, kalkoenslurp, misbredie, varkbossie	(Kumar *et al.*, 2014)
	Tswana	Imbuya, thepe	(Kumar *et al.*, 2014)
	Venda	Umfino, vowa, Morogo	(Kumar *et al.*, 2014)
	Xhosa	Umfino, umtyuthu, unomdlomboyi	(Kumar *et al.*, 2014)
	Zulu	Imbuya, isheke	(Kumar *et al.*, 2014)
6	Congo	bitekuteku*Amaranthus* viridis, Kinshasa Province	(Kumar *et al.*, 2014)
7	Indonesia	Bayam	(Rastogi and Shukla, 2013)
8	Laos	Pak hom	(Rastogi and Shukla, 2013)
9	Siri Lanka	Thampala	(Rastogi and Shukla, 2013)
10	India	Rangasak, ramdana, rajeera, lalsak, lalsagchauli; cheera; koyagura; kuppaikeerai; thotakura	(Kumar *et al.*, 2014)
11	China	Een choy, Yin choy, In-tasi, Hsien tasi, xiancai, Hiyu, Hon-toi-moi,	(Kumar *et al.*, 2014)
12	Japan	Hiyuna	(Kumar *et al.*, 2014)
13	Spanish	French: calalou, callaloo	(Kumar *et al.*, 2014)
14	Fulani	Boroboro	(Kumar *et al.*, 2014)
15	Ghana	Madze, efan, muotsu, swie	(Kumar *et al.*, 2014)
16	Sierra Leone: Grins	Creole, hondi, Mende	(Kumar *et al.*, 2014)
17–19	Nigeria: Hausa	Alayyafo	(Kumar *et al.*, 2014)

	Yoruba	Efo tete, Eforiro	(Kumar *et al.*, 2014)
	Igbo	Igbo inene; Temne: ka-bonthin	(Kumar *et al.*, 2014)
20	Malawi:	Bonongwe	(Kumar *et al.*, 2014)
21	Philippines	KulitisIlongo, uray Tagalog	(Kumar *et al.*, 2014)
22	Indonesia:	Bayam, Bayammenir, Java, Bayamkotok Sumatra, Chaulai	(Kumar *et al.*, 2014)
23	Thailand:	Pak-komhat,pak. Phomsuan	(Rastogi and Shukla, 2013)
24	Jamaica:	Callaloo	(Kumar *et al.*, 2014)
25	Vietnam	Yan yang	(Rastogi and Shukla, 2013)
26	Peru	Anchita, achos, achis,incajtaco,coimi and kiwicha	(Rastogi and Shukla, 2013)
27	Bolivia	Coimi, Millmi	(Rastogi and Shukla, 2013)
28	Ecuador	Sangoracha, alaco	(Rastogi and Shukla, 2013)
29	China	Hiyu, hon-toi-moi, yin choy, hin choy, een choy, tsai	(Rastogi and Shukla, 2013)
30	India	Chhaulai, Rangasak, ramdana, rajeera, lalsak, lal sag	(Kumar *et al.*, 2014)
31	Malaysia	Bayamputeh, bayarnmerah	(Kumar *et al.*, 2014)
32	Caribbean	Spinach, bahaji callaloo, calaloo, etc	(Ramdwar, Chadee and Stoute, 2017)
33	English:	Prickly amaranth, needle burr, spiny amaranth, thorny amaranth, pigweed, African spinach, foxtail	(Kumar *et al.*, 2014)
34	Hindi:	Kantachaulai, Gujarati: Kantalodhimdo, Kantanudant. Manipuri: Chengkruk Marathi:	(Kumar *et al.*, 2014)
35	Tamil:	Mullukkeerai, Malayalam: Kattumullenkeera	(Kumar *et al.*, 2014)

36	Telugu:	Mullatotakura Kannada: Mulluharivesoppu Bengali: Kantanotya Oriya: Kantaneutia Sanskrit: Tanduliuyah	(Kumar *et al.*, 2014)
37	French	amarante; brede de Malabar, queue de renard, discipline des religieux	(Kumar *et al.*, 2014)
38	Mexico	Zac-tec	(Kumar *et al.*, 2014)
39	Portugal	Caruro	(Kumar *et al.*, 2014)
40	Sweden	Mchicha	(Kumar *et al.*, 2014)
41	America	"Chowlai"	(Reyad-ul-Ferdous *et al.*, 2015)
42	Philippines	Kulitis	(Rastogi and Shukla, 2013)
43	Thailand	Pakkhom ha, pak, khomsuan	(Rastogi and Shukla, 2013)

2.5 Potential Nutritional Value and Health Benefits of *Amaranthus Leaves*

The production of Staple food crop appears unable to meet up with the re-quired food that feeds the increasing global population. Similarly, staple foods are inadequate in essential nutrients to optimize wellbeing (Tsegay et al., 2014). Hence, there are increased studies on food that are easily grown and are nutrient-dense in composition to tackle hunger, mitigate and alleviate food and nutrition insecurity (Rastogi and Shukla, 2013). Amaranthus-based food can be a contributor to food and nutrition security, especially among the less privileged, who are unable to ac-cess animal protein and other essential nutrient food sources like calciferous vegetables. This is because Amaranthus leaves are reported as one of the plants rich in essential nutrients among other traditional vegetables, of great importance, besides its use for religious practices in the place of its origin (Srivastava, 2011; Achigan-Dako, Sogbohossou and Maundu, 2014). Amaranthus has been known to have relatively high nutritional value compared to exotic vegetables that are mostly preferred. However, it has been established that the contribution of the micro-nutrient status of Amaranthus depends upon their retention capacity of the nutrients after processing and cooking methods (Yang and Keding, 2009). Amaranthus leaves are rich in protein and micronutrients such as zinc, calcium, magnesium, phosphorus, folic acid, potassium, iron, and vitamins A–C but low in carbohy-drates(Okpara et al., 2013; Ramdwar, Chadee and Stoute, 2017). Amaranthus leaves are low in calories. Consequently, they must be complemented with foods rich in calories. Amaranthus is cholesterol-free, making it a food option for those on strict diet prescription, such as weight losing formulation. A study confirms that the nutrient content per 100g fresh weight of Amaranthus was compared to cabbage and was reported higher in protein, calcium, iron, β-carotene, and vitamin C (Ramdwar, Chadee and Stoute, 2017). Likewise, lettuce was compared with Amaranthus, and Amaranthus showed a higher nutritional content of 7 times more iron, 13 times more vitamin C, 18 times more vitamin A, and 20 times more calcium than other similar plants (Srivastava, 2011). Since Amaranthus yields significantly within the shortest period, it could be a promising crop to tackle food security and food and nutrition insecurity (Singh, 2017). Additionally, Amaranthus leaves are rich in antioxidants and phytonutrient properties. Thus, they are endowed with an essential dietary nutrient that could be explored as a preventive measure and healing effects to the essential nutrient-deficient individual (Jimoh, Afolayan and Lewu, 2019). The common names of Amaranthus in South Africa and other countries are described in Table 2.

Amaranthus has been demonstrated to have medicinal effects in traditional medicine (Topwal, 2019). For instance, the dried Amaranthus crop has been burned in Benin for the preparation of potash. Similarly, the root of Amaranthus has been boiled with honey in Senegal and was used as a laxative for infants. The water of macerated Amaranthus plants has been used in Ghana as a wash to treat pains in the limbs. Ethiopians have used A. *cruentus* as a tapeworm expellant (Alercia, 2013). The ash from Amaranthus stems has been used for wound dressing in Sudan, also in Gabon. Moreover, Amaranthus has been suggested to assist people with low red blood cell count (Alercia, 2013; Rastogi and Shukla, 2013). The leaves of Amaranthus have medicinal properties that are beneficial to the health of young children, lactating mothers, and patients with constipation, fever, haemorrhage, anaemia, or kidney complaints. Amaranth is rather included among the diuretics (substances that promote increased urine production) (Alercia, 2013). Amaranthus leaves have been used as anti-inflammatory (Alercia, 2013). The ability of Amaranthus vegetables to promote health benefits is largely attributed to the nutritional and bio-active compounds endowed in Amaranthus. For instance, studies on Amaranthus spinosus have been investigated, and a wide and spectrum of its pharmacological actions have been explored (Kumar et al., 2014). The plant possesses hepatoprotective, antioxidant activity, water extract of the plant has a significant immune-stimulating activity, and extracts had been used as an antidiuretic, antiviral, antimalarial, antibacterial, anti-inflammatory, antimicrobial, and hepatic disorders (Jhade et al., 2009; Kumar et al., 2014). It is used internally in the treatment of internal bleeding, diarrhoea, and excessive menstruation (Baral et al., 2011; Kumar et al., 2014). Amaranthus has not only been of benefits in traditional medicine, ornamental and industrial benefits but also, Amaranthus has widely been investigated for its nutritional composition, and have been reported to have potentials in human and animal nutrition; hence, they are identified as rich in the following dietary nutrient (Achigan-Dako, Sogbohossou and Maundu, 2014; Ganjare and Raut, 2019).

Fiber: Amaranthus has been considered a rich source of fibre, which constitutes soluble and insoluble (Sarker and Oba, 2019; Chidozie Ogwu, 2020). Therefore, the inclusion of Amaranthus leaves as one of the ingredients in a daily diet can be of advantage to the consumers, as it aids digestion and as well as beneficial, by way of easing bowel movement, managing weight and thereby, reducing non-communicable diseases, especially heart disease and diabetes. High protein and fibre components of Amaranthus can assist in reducing appetite, thereby promoting individual weight loss and healthy living (Venskutonis and Kraujalis, 2013; Sarker and Oba, 2019). Due to the fibre content, Amaranthus digest easily; hence, it can be beneficial to convalescents and those recovering from illnesses. In addition, its leaves have been known to treat diarrhoea and haemorrhages.

Protein. Dark green leafy vegetables, including Amaranthus leaves and the grain, are rich sources of plant protein (Schnetzler and Breene, 2018). Amaranthus is among the vegetables that are rich in essential amino acids (Njeme, Goduka, and George, 2014). Protein from the plant has been regarded as much healthier protein than protein from the animal. This is because plant sources are having less or no fat and, therefore, cholesterol-free. It has been noted that bad cholesterol in the body leads to cardiac problems. Amaranth leaves are known to lower bad cholesterol, which is responsible for many cardiac problems.

Also, it is claimed that consumption of Amaranthus leaves suppresses appetite since they are rich in protein (Ramdwar, Chadee and Stoute, 2017). A protein-rich diet can suppress hunger because it reduces insulin levels in the blood, thus con-trolling the appetite. Amaranthus is gluten protein-free. Thus, it can be beneficial to those who are gluten intolerant. Proteins are macronutrients required by humans for the growth and maintenance of the human system. It plays a critical role in regulating different activities at the cellular, tissue, and organ levels of the body, providing the right hydrolytic environment (Jimoh, Afolayan and Lewu, 2018). Plant and animals are rich sources of protein. Plant proteins form a large part of the human diet. However, deficient in one or more essential amino acids are regarded as incomplete protein. If certain food supplies enough of seven out of the eight essential amino acids, the lacking amino acid is referred to as the "limiting amino acid". These limiting proteins (lysine, threonine, methionine, and tryptophan) could be found in plants, such as Amaranthus. Hence, Amaranthus has been identified to have lysine in a significant amount. Moreover, and lysine has been known to help to promotes hair growth and slows aging processes and enhances good skin. In addition, people who suffer hair loss or the early greying of hair can benefit maximally by including Amaranthus leaves in their diet. In addition, lysine is an essential amino acid, which is essential for energy production and a good precursor for the absorption of calcium. Both Amaranthus leaves and the grain isa rich source of protein. Currently, *huaútli* is a superfood, and it is gaining worldwide recognition as a high-protein edible plant with great potentials to provide a solution for the world's hunger and to tackle malnutrition challenges (Achigan-Dako, Sogbohossou and Maundu, 2014). The seeds of Amaranthus have eight to nine grams of protein in a one-cup serving, offering a nutritionally complete plant food with all the essential amino acids needs of the human body, without gluten.

Iron: Amaranthus is rich in iron and it is required for producing red blood cells and is also needed for cellular metabolism. However, iron found in Amaranthus leaves can be maximized through cooking methods like the blanching method of food processing, which has been known to improve the bioavailability of iron (Yang and Tsou, 2006). In addition, iron could be made available with the presence of vitamin C-rich foods or supplements in the diet. This is because vitamin C, like lemon, apples, or orange, have been proven to facilitate maximum absorption of iron in the blood (Sharma, 2003; Yang and Tsou, 2006). This implies that maximum iron absorption and can help fight anaemia. In addition, iron-rich foods, such as Amaranthus, can be explored to combat iron deficiency challenges. Hence, it is a source of immunity boosters to the world where the iron problem prevails.

Vitamin C. Leafy green Amaranthus are rich in vitamin C. It is reported that one cup of boiled and drained Amaranthus leaves contains 90% vitamin C daily dietary requirement (Achigan-Dako, Sogbohossou and Maundu, 2014). Vitamin C is a water-soluble vitamin, and it is essential and potent to fight infections as well as enhance the quick healing of scurvy and other wounds. Besides vitamin C, phenolics and flavonoids are phytochemical compounds responsible for most of the antioxidant activity in fruit and vegetables; hence, they are identified as essential for the biosynthesis of collagen, carnitine, which is a metabolism booster and a source of antioxidants and anticarcinogenic compound (Jiménez-Aguilar and Grusak, 2017; Ganjare and Raut, 2019). These compounds occur as secondary metabolites that act as defences against several diseases like atherosclerosis, including cancer, arthritis, cataracts, emphysema, retinopathy, neurodegenerative and cardiovascular disease (Sarker and Oba, 2018). As a result, there is increasing interest in the exploitation of plant-based drugs. The plant-based drug is considered a safe and cost-effective alternative to other therapy (Jimoh, Afolayan and Lewu, 2019). Therefore, the inclusion of Amaranthus leaves as a regular part of a diet is a promising nutraceutical therapy that can be explored as a preventive mechanism against non-communicable diseases ravaging people's life.

Vitamins are organic compounds, having essential nutrients that cannot be synthesized by the body; hence, they must be derived from the diet consumed, including Amaranthus leaves diet (Lee et al., 2017). Essential vitamins and minerals are good boosters of immunity (Alpert, 2017). Several studies have linked diets rich in vegetables like Amaranthus to have the potential to reduced risks of chronic diseases or vitamin deficiency syndromes (Hu, 2002; Lee et al., 2017). Similarly, studies report that a healthy lifestyle and ample consumption of vegetables and fruits are linked to lowering non-communicable diseases, including heart diseases (Randhawa et al., 2015). Hence, it is generally agreed that people who consume adequate fruits and vegetables are usually healthier and free from hidden hunger and its consequential issues. Fruits and vegetables, including Amaranthus, are good sources of vitamins and minerals.

Vitamin A. It is reported that Amaranthus leaves are endowed with vitamin A properties amounting to 73% of dietary needs. A cup of Amaranthus leaves has been proven to supply 97% of daily human dietary needs (Achigan-Dako, Sogbohossou and Maundu, 2014). Vitamin A is essential for several processes in the body. It is good for the maintenance of a healthy vision. It aids the functioning of the immune system and organs, as well as aids the proper growth and development of babies in the womb (Pennington and Fisher, 2010).

Vitamin K. Vitamin K is a fat-soluble vitamin. It occurs naturally in two forms; phylloquinone (vitamin K1) and menaquinone (vitamin K2) (Dennehy and Tsourounis, 2010). It has been reported that phylloquinone levels in fruits and vegetables range from extremely low to quite high (Lee et al., 2017). Green leafy vegetables, including Amaranthus leaves, have been reported to have the highest amount of vitamin K (DiNicolantonio, Bhutani and O'Keefe, 2015; Lee et al., 2017). Vitamin K is required for wellbeing because it plays an important role in blood clotting and also essential for healthy bones because it promotes osteoblastic activity and strengthens the bone mass (Lee et al., 2017). Also, vitamin K has been known to control neural damage in the brain. Hence, it is beneficial for those who suffer from Alzheimer's disease.

Vitamin K as a cofactor in the carboxylation of osteocalcin has been identified to help to improve its affinity for calcium and promote binding to hydroxyapatite, thereby improving healthy bones. (Asensi-Fabado and Munné-Bosch, 2010).

Calcium. Amaranthus leaves have been reported as a good source of calcium. A cup of Amaranthus leaves provides a significant (28%) amount of calcium (Achigan-Dako, Sogbohossou and Maundu, 2014; Beswa et al., 2016). Calcium is an essential mineral that can be beneficial to humans especially, people who have osteoporosis and other calcium deficiency-related health problems.

Potassium. Amaranthus has been investigated for its mineral content and was reported to contain significant content of potassium (Nwaogu, Ujowundu and Mgbemena, 2006; Srivastava, 2011). Potassium is an essential nutrient largely found in body cells. It is the main electrolytes that play an important role in the living cell. It maintains fluid balance. Hence, it is crucial for muscle contraction, nerve conduction as well as providing acid-alkaline balance in the body (Stone, Martyn and Weaver, 2016). Adequate intake of potassium can contribute to the maintenance of healthy blood pressure and heartbeat. However, it has been re-ported that the low intake of dietary potassium plays a role in the development of cardiovascular diseases, including high blood pressure (Palmer and Clegg, 2016). Hence, the adequate intake of dietary potassium from vegetables like Amaranthus may contribute to prevent and reverse high blood pressure, provided there are no other underlying health challenges. However, such a dietary lifestyle needs to be consumed along with more fruits and vegetables as good sources of essential vitamins and minerals because fruits and vegetables have been reported as good sources of potassium as opposed to sodium (Slavin and Lloyd, 2012; DiNicolantonio, Bhutani and O'Keefe, 2015). Traditional leafy green vegetables like Amaranthus have been identified as a super-food that can provide the body with essential vitamins and minerals vital for optimum wellbeing (Randhawa et al., 2015). The intake of dietary nutrients, including potassium, has been reported low among the under-privileged population (Phillips et al., 2015). White fruits and vegetables, such as (bananas, white peaches, parsnips, cauliflower, garlic, mushrooms, onions, potatoes, shallots, turnips, corn, and kohlrabi) have been reported as rich sources of fibre, magnesium, and potassium. However, they may be expensive for the under-privileged population (Weaver and Marr, 2013). However, vegetables like Amaranthus are cheap yet with great potentials for essential nutrients, including potassium. Moreover, Amaranthus could be naturally grown since it is easily cultivated with little attention.

The B vitamins. Amaranthus leaves are rich sources of vitamins B complex group: riboflavin, niacin, folates, vitamin B6, vitamin B1 (thiamine), vitamin B2 (Riboflavin), vitamin B3 (niacin), vitamin B6 (pyridoxine), vitamin B9 (folates), vitamin B12 (cobalamins cyanocobalamin) and others (Alercia, 2013). The B vitamins are beneficial as they are needed for optimal mental and physical health as well as help prevent birth defects in newborn babies (Randhawa et al., 2015). B vitamins are regarded as cofactors for enzymes that are involved in the energy-producing metabolic pathways for carbohydrates, fats, and proteins. B vitamins also play an important role in maintaining functions of the nervous system (Dai and Koh, 2015). Vitamin B9, better known as folate, plays a central role in the one-carbon metabolism in the nucleotide synthesis, in the metabolism of homocysteine. However, the bioavailability of this plant also crucial to their maximum benefits to humans

2.6 Bioavailability of Micro-nutrients in *Amaranthus Leaves*

Several studies reported that plant foods, including Amaranthus and other dark leafy vegetables, contain some levels/concentration of antinutritional compounds like phytates, oxalates, and nitrates, otherwise call antinutritional factors (Sanz-Penella et al., 2012). These compounds are believed to be present in a variety of plant food, and it has been reported that they can reduce the absorption of micro-nutrients, hence, leading to the lowering or rather hindering the bioavailability of essential nutrients in plant food (Jimoh, Afolayan and Lewu, 2018). Some of the antinutritional factors that interfere with the absorption of some vital nutrients in the diet include phytic acid, oxalates, pro-anthocyanidin, tannin, and dietary fibres, which are known to reduce the bioavailability of the nutrients after consumption (Funke, 2011). Among other vegetables, Amaranthus has been considered a rich source of micro-nutrients and other dietary minerals. Amaranthus is considered as a storehouse for potassium, calcium, particularly iron, zinc, magnesium with an appreciable number of carotenes and vitamins A which have been investigated for optimum wellbeing (Jimoh, Afolayan and Lewu, 2018). For ex-ample, a study report that raw amaranth is considered rich in micro-nutrients, particularly iron and vitamin C. (Funke, 2011). Amaranthus was compared with common vegetables, such as cabbage and spinach and was rated higher in terms of the nutritional composition (Ramdwar, Chadee and Stoute, 2017). Nevertheless, the bioavailability of the micro-nutrients in Amaranthus depends on their methods of food preparation, consumption, as well as the biological interactions between their phytonutrients content in Amaranthus and the nutrients available in added ingredients. The stability of beta-carotene, for example, was said to be more enhanced with vitamin C, lutein, polyphenols, and lycopene when interacted (Jiménez-Aguilar and Grusak, 2017). This implies that when Amaranthus is combined with food rich in these compounds, the concentration of beta-carotene will be greater since Amaranthus is being re-discovered, as plant crop of great im-portance. The most widely grown species Amaranthus, their synonyms and common names are described in Table 3. below

Table 2-3: Some of the most widely grown species and their common name

Species	Synonyms	Common Name	References
Amaranthusblitum L	*A. lividus*L. *A. oleraceus*L.	Amaranth, wild slender amaranth, pigweed, purple amaranth, amarantesauvage, amaranteblette,amaranto, bredo,(Po) mchicha, (Sw)	(Grubben, 2004a)
Amaranthuscuruentus	*A. paniculatus*L. *A. sanguineus*L. *A.hybridus*L. subsp. *cruentus* (L.) Thell. var.*paniculatus* (L.) Thell.	Amaranth, African spinach, Indian spinach, amarante, brède de malabar,amaranto, bredo,mchicha Red/purple amaranth	(Grubben, 2004b)
Amaranthuscaudatus	Love-lies-bleeding, red-hot cattail,	African spinach, Indian spinach,brèdemalabar, Bredo,mchicha,	(Agong, 2006)
Amaranthusdubius	*Amaranthus tristis* auct. Non-L.	Spleen amaranth, pigweed,amarante, brède de malabar, Amaranto, bredo,mchicha,	(Grubben, 2004c)
Amaranthushypochondriacus	*Ahybridus* auct. Non-L.	Prince’s feather, amaranth,amarante, brèdemalabar,amaranto, bredo,mchicha,prince-of-wales feather	(Jansen, 2004a)
*Amaranthusspinosus*L.		Spiny amaranth, prickly amaranth, spiny pigweed,amaranteépineuse, épinardmalabar, épinard	(Jansen, 2004b)

Amaranthus. *Thunbergia*		piquant,amaranto, bredo,mchicha, Wild amaranth, wild spinach, pigweed,amarantesauvage,amaranto, bredo,mchicha, Thunberg's *Amaranthus*	(Grubben, 2004d)
Amaranthustricolor	*A. tristis* L. *A. gangeticus* L	Amaranth, Joseph's coat,amarante, brède de malabar, Amaranto, bredo, Mchicha, Chinese spinach, fountain plant, tampala, summer poinsettia	(Grubben, 2004e)
Amaranthusviridis	*A. Gracilis* Desf. Ex Poir.	Green amaranth, local tete, african spinach, Amaranteverte, épinard vert, épinard du Congo, Amaranto, mchichacalalu, slender amaranth	(Jansen, 2004c)

2.7 Indigenous Knowledge System and, Uses of *Amaranthus in* America, Asia, and Africa

Indigenous knowledge can gradually disappear due to a lack of adequate transfer of knowledge to the younger generation. The loss of indigenous knowledge system of food may hinder people from benefitting from the available and accessible food resources thus, depriving people of the nutritional value embed in indigenous food, including Amaranthus (Dweba and Mearns, 2011). Hence, conserving the indigenous knowledge system becomes a vital drive for food-based approach. This review agrees with the statement that, transfer of indigenous knowledge system of traditional vegetables is promising and can promote the accessibility of their endowed nutrient. Amaranthus is a common food plant that has been used in resource-poor rural populations. Hence it is linked with the poor (Maestr, 2018).

Physiologically, A. *spinosus* is a straight plant, a perennial herb with diverse colours, and is widely distributed throughout the tropics and warm temperate regions of Asia from Japan to

Indonesia, India, the Pacific islands, native to tropical America and Australia as a weed and as a cultivated crop. It is a common weed found in waste places, roadsides, and path sides and near rivers in West Africa, Ghana (Maestr, 2018). The plant has a long history of usage in traditional medicine against various ailments around the world, subtropical and Himalayan regions, and is distributed in lower to middle hills (3000–5000 ft) of the entire Northeastern Himalayas (Maestr, 2018). A. spinosus Linn. One of the medicinal plants of Eastern Himalaya, especially of Sikkim Himalaya, is known as prickly Amaranthus (Maestr, 2018). Amaranths leaves and grains are indigenous foods of Incas and Aztecs in pre-Columbian times. Among the Aztecs, Amaranth flour was used to baked im-ages of their patron deity, Huitzilopochtli, more prominently during the festival called *Panquetzaliztli*, symbolizing means "raising banners". The Mixtec's of Oaxaca also greatly recognized the role of Amaranths. Amaranths were made into a paste and were used to stick the precious postclassic turquoise mosaic covering of the skull, it was also used as a form of tribute payment. Its name in Nahuatl was *huauhtli* (Maestr, 2018).

Furthermore, all Amaranthus has been used for forage since it was regarded as weeds, but it also has been included in the human diet as an ingredient with great potential for wellbeing. A. caudatus was a commonly dispersed staple food of hunter-gatherers in South America and India. The species originated as one of the staple foods of the ancient inhabitants of the Andean region (Maestr, 2018).

Several Amaranthus crops are widely grown in Central and South America; however, there are also grain amaranths that are genetically distinct from the weedy species, which are believed to have evolved from wild populations (Vigueira, Olsen and Caicedo, 2013).

Spinosus Linn of the family of *Amaranthaceae* is traced to tropical America. A. spinous is spiky in appearance, commonly called "pigweed" (Achigan-Dako, Sogbohossou and Maundu, 2014). Amaranthus spinosus is also one of the most common species of plant in India. Amaranthus spinosus is generally known for their therapeutic properties "Kate *waliChaulai* (*Kanatabhajii)*"in Hindi (Kumar et al., 2014). Amaranthus spinosus is cultivated in India, Sri Lanka, and it spread across the tropics of most continents of the world (Central America, South America, Caribbean, Africa, and the warm temperate regions of Asia) from Japan to Indonesia, the Pacific Islands, and Australia where it grows as a volunteer crop or weed although it was also cultivated. Besides the supply of food, Amaranthus spinous can tackle the health challenges of malnutrition while optimizing wellbeing. The healing powers of traditional herbal medicines, including Amaranthus, have been realized since ancient times. It is reported that almost 65% of the world populations have access to traditional medicinal plant and their knowledge system.

Spinosus amaranths have erected spikes, a yearly or perennial herb with diverse colours ranging from green to purple. In India, spiny Amaranthus are used for food and play a vital role in the Indian traditional system of medicine (Ayurveda). The plant has been used as febrifuge, antipyretic, laxative, and diuretic. Amaranthus spinous is used for treating digestible, bronchitis, used to stimulate appetite, in-creased bile secretion, it promotes lactation, increases haemoglobin, stomach flatulence, anorexia (restricting oneself from eating for fear of gaining weight), blood diseases, burning sensation, leucorrhoea (yellowish discharge from the female genital part, leprosy, and piles). It is reported that Amaranthus spinous is endowed with phytochemicals, which can destroy free radicals while boosting immunity, thus stressing its importance as a medicinal plant with great potentials (Baral et al., 2011; Kumar et al., 2014). Amaranthus contains active biochemical compounds that are reported in several studies. It is a rich source of alkaloids, flavonoids, glycosides, phenolic acids, steroids, amino acids, terpenoids, lipids, saponin, *betalain*, b-sitosterol, stigmasterol, linoleic acid, rutin, catechuic tannins, and carotenoids. Further studies on Amaranthus spinous have been conducted by various researchers, and a wide range of its pharmacological actions have been explored, which may include antidiabetic, antitumor, analgesic, antimicrobial, anti-inflammatory, and anti-spasmolytic a bronchodilator, hepatoprotective, spermatogenic, antifertility, antimalarial, antioxidant properties (Kumar et al., 2014). Amaranthus spinosus also use in internal bleeding, diarrhoea. The next section presents several studies on Amaranthus some traditional uses in America, Asia, and Africa.

2.8 Traditional Uses of *Amaranthus in* America

Amaranthus was cultivated 6000–8000 years ago by the mighty Aztecs. The Mixtec's of Oaxaca esteemed this plant. During the pre-Columbian civilizations, the turquoise mosaic covering the skull within Tomb 7 at Monte Alban was kept together by the sticky paste of Amaranthus. Though it was a staple food of the Az-tecs, However, the cultivation of Amaranthus decreased and almost disappeared in colonial times, under Spanish conquest (Srivastava, 2011; Barku, Ahiadu and Abban, 2013). In ancient times of the Mesoamerica, Amaranthus seeds were commonly used by the Aztec/Mexica. Hence, the cultivation of Amaranthus was significant because they use it for tribute payment (Rastogi and Shukla, 2013).

It played a great role in their worship of gods (AncientGrains, 2018; Maestr, 2018). During the festival called *Panquetzaliztli* (raising banners), the Aztecs used the mixture of Amaranthus and honey to build and bake images of their patron deity *Huitzilopochtli*. It is a ceremony where Amaranthus dough figurines of *Huitzi-lopochtli* were carried around in processions, after which. It is broken, distributed among the population for eating (Rastogi and Shukla, 2013. These practices made amaranths unable to survive as a staple food. All this happened on the arrival of the Spanish with Cortez when efforts were made to force Christianity on the pagan natives, and Amaran-thus grain was forbidden, fields burned, while cultivators were punished severely (AncientGrains, 2018). Currently, Amaranthus is regaining its importance. Hence, it is grown in a few locations in the United States (Achigan-Dako, Sogbohossou and Maundu, 2014). More of the total species of Amaranthus exist in America, and they include: A. *cruentus* A. *hypochondriacus,* A. *caudatus,* A. *tricolor,* and A. *dubius,* A. *blitum,* A. gangeticus, A. *spinosus,* A. *vridis*. However, besides the common ones are, A. *retroflexus* and its congener, A. i*hybridus* is native to North America, but is currently established as toxic weeds world-wide (Peter and Gandhi, 2017; Weston et al., 2019). This implies that not all Amaranths are consumable, as some could be weed and perhaps toxic. Hunter and gatherers were the first to consume native food like Amaranthus in both North and South America before the domestication (Park, Hongu and Daily, 2016). In America, Amaranthus seeds are consumed whole, it is toasted or milled into flour to make bread, noodles, pancakes, cereals, granola, cookies. In addition, the seed is popped like popcorn or flaked like oatmeal. Over 40 amaranth-based products are produced and are currently on the market in America. Amaranthus are also used for animal feed, it is used for textile dyeing, and it is among the ornamental plant; hence, it provides beauty to many environments. In the past two decades, there has been an increasing trend of the replacement of synthetic dyes with natural pigments from plants (Alemayehu, Bendevis and Jacobsen, 2015). The pigment in Amaranthus can be used to prepare yellow and green dyes, red amaranth pigment has been used as a colorant in foods and medicines (Alemayehu, Bendevis and Jacobsen, 2015). In America, the roots of Amaranthus have been used to produce dye though, it fades very slightly and resulted in a light colour. In Bolivia and northwestern Argentina, people used red dye of Amaranthus leaves to colour alcoholic beverages, while in Mexico and the Southwestern United States it is used for colouring maize dough and colouring foods and beverages (Rastogi and Shukla, 2013).

Species of A. *cruentus* were primarily used by Mexicans to produce typical sweets called "alegera". The *Alegera* is a common traditional snack that is made by a process where

Amaranth grains are toasted and mixed with honey or chocolate; they are popped and mixed with honey to make jaggery or molasses as candy types of products (Rastogi and Shukla, 2013). It has been investigated that the green leafy Amaranthus possess the ability to maintain green foliage during the summer period. Therefore, it has been used as a rich source of complete amino acid, iron, and other essential nutrients for humans and livestock (Peter and Gandhi, 2017). Although, ingestion of the fresh green or old Amaranthus leaves has been linked with out-breaks of livestock poisoning(Reyad-ul-Ferdous et al., 2015). Before now, United State has been the leading producer of grain Amaranthus, and it is used in small scale businesses for making food products, but, in the last decade, China happens to be the largest grain Amaranthus producing area, though the Chinese uses Amaranthus as forage, rather than harvesting it as grain (Rastogi and Shukla, 2013).

2.9 Uses of *Amaranthus in* Asia

In India, Amaranthus is a common wild vegetable. It is a weed that is cultivated and commonly known as "*Chowlai.*" Notably, Amaranthus holds a vital role in Asian traditional (herbal) medicine. For example, Amaranthus spinous juice has been extracted and used by the tribe of Kerala to prevent swelling around the stomach, while the leaves are boiled alone and consumed for 2–3 days to cure jaundice (Ganjare and Raut, 2019). Additionally, in Asia, the plant ash in a solution is used to wash sores, and the plant sap is used as an eyewash to treat ophthalmia as well as convulsions in children. In the Indian traditional system of medicine (Ayurveda), the plant is used as a febrifuge (medicine that reduces fever), laxative (a drug that stimulates bowel evacuation) effective diuretic (a drug that effectively stimulates passing out of urine) (Ganjare and Raut, 2019). The Himalayas region consumed Amaranthus grain as a minor cereal. Moreover, its usage in food preparation, it is a popular medicinal plant used to treat bronchitis, appetizer, bilious-ness, galactagogue, hematinic, stomach effects, nausea, flatulence, anorexia, blood diseases, burning sensation, leucorrhoea, leprosy, piles, and as a treatment for hallucination, healing of wounds and rheumatism as well as arrest the coughing up of blood. All parts of the plant are known to contain medicinally active constituents [101,102]. An infusion of Amaranthus leaves is used by Sikkim when there is a stomach disorder, such as indigestion and anemia. Ethnic use of this plant is mainly with village people of Sikkim (Kumar et al., 2014; Mitra, Ghosh and Kumar Mitra, 2014). Likewise, in India, the root extract is given as a vermicide among the Santhali and Paharia in eastern Bihar, while an aqueous decoction of the plant is given to check chronic diarrhoea in Southern Orissa (Kumar et al., 2014). In addition, the Nepalese and some tribes in India apply Amaranthus spinous to induce abortion.

Moreover, Amaranthus seeds are eaten raw in India and other places, it is mixed with other grains or processed into flour and is used to make food products. Some species have been used in desert areas of India, where the seeds of these species have been used as famine foods) (Rastogi and Shukla, 2013). Similarly, in South-East Asia, a decoction of the root is used to treat gonorrhoea and is also ap-plied as an emmenagogue (a substance that stimulates or increases menstrual flow) and antipyretic (an active medical substance that reduces fever) (Mitra, Ghosh and Kumar Mitra, 2014). In mainland South-East Asia, the rainy season is linked with malaria-endemic. Hence, Amaranthus spinous bark decoction is taken in a volume of about one Liter three times a day where malaria is prevalent. In India, the leaves of Amaranthus *caudatus* are used as a tea to relieve pulmonary problems and piles. They are used in the purification of blood, strangury in scrofula, and as a diuretic. The boiled leaves are used in swellings and stomach upset (Topwal, 2019). Other Asian countries have used Amaranthus: in traditional medicine, Amaranthus spi-nous is used to treat diarrhoea. The root is also used for treating toothaches; in Southeast, in Malaysia, Amaranthus spinous is used as a cough syrup for relieving affected breathing in acute bronchitis (Ganjare and Raut, 2019). The Chinese also use Amaranthus spinous in traditional medicine to treat diabetes. The seeds are used as a poultice for broken bones, smooth paste of leaves and roots have been explored as cataplasm, for a relief from skin diseases/disorders, such as abscesses, bruises, burn, eczema, inflammation, gonorrhoea, menorrhagia and wound (Ganjare and Raut, 2019). Still in Asia Amaranthus root paste with equivalent volume of honey has been used to control vomiting and, when mixed with sugar and water it helps in controlling dysentery. A mixture with black pepper in ration 1:3 that is (a part black pepper and 3 parts root paste) is administered twice daily, for tackling rabies (Ganjare and Raut, 2019).

2.10 Uses of *Amaranthus in* Africa

Although it is still unknown how Amaranthus arrived in Africa, however since 1980, Amaranthus has been identified as a promising food plant and a drought-resistant plant, a smart food for climate change(Achigan-Dako, Sogbohossou and Maundu, 2014). It is widely found in Africa as an ornamental plant or weed throughout the continent, from Senegal to Nigeria in West Africa, and from Equatorial Guinea to Zaire central Africa (Achigan-Dako, Sogbohossou and Maundu, 2014). Species have also been identified in Morocco, Ethiopia, and Sudan (Achigan-Dako, Sogbohossou and Maundu, 2014). African traditional vegetables and Amaranthus are progressively recognized as promising food plants with both macro-nutrients and micronutrients, besides its being a source of bioactive compounds in the diets of most rural populations in Africa (Achigan-Dako, Sogbohossou and Maundu, 2014). The continent is endowed with varieties of other vegetables. The most common African leafy vegetable is Amaranthus. Although it is agreed that about 60–75 species of Amaranthus exist, only 17 of the species are edible leaves and three-grain purposes species (Achigan-Dako, Sogbohossou and Maundu, 2014). Several species are often considered weeds because they grow naturally on fallow lands and even by the roadsides with no attention (Maseko et al., 2017). A few species among the leafy species are grown as the most common species in tropical Africa markets. Grain amaranth is not commonly cultivated in Africa. Many of the rural populations don't utilized the seed as food because they are less informed that Amaranthus seeds are edible, a such, where Amaranths are grown for seed purposes, they must be the introduced varieties of American origin (Grubben and Denton, 2004). In recent times, however, few farmers have been engaged seriously in the growing of grain Amaranthus such that they are supplying some millers and supermarkets in Zimbabwe, Kenya, Uganda, and Ethiopia. (Achigan-Dako, Sogbohossou and Maundu, 2014; Cernansky, 2015). Across Africa, most of the staple foods are predominantly starchy since they include cereals, such as maize, rice, wheat, and root crops. Most staple foods are considered inadequate in essential amino acids, such as lysine and tryptophan (Hoddinott, Rosegrant and Torero, 2012). Traditional vegetables, such as Amaranthus, are suggested to complement the nutritional inadequacies of such starchy staples (Peter and Gandhi, 2017). Phytochemicals and bioactive compound are present in Amaranthus sleave hence are also recognized as anticancer potential, which benefits humans, by inhibiting the proliferation of liver, breast, and colon cancer cell (Joshi and Verma, 2020). There are still gaps in the information on the potentials and uses of the popular Amaranthus in Africa. A. *cruentus* is common in Africa, and Amaranthus *caudatus* are widely used as ornamental and grain Amaranthus. The variety of *cruentus* was introduced recently to Southern Dahomey (Benin), which proved to be drought resistant. The third American Amaranthus (A. *hypochondriacus)* was introduced into East Africa in 1940 (Achigan-Dako, Sogbohossou and Maundu, 2014). In Africa, traditional vegetables like Amaran-thus appear to be the most recognized, perhaps. It is the most affordable among other traditional vegetables (Achigan-Dako, Sogbohossou and Maundu, 2014). It is high in fibre, low in calorie, hence, is used to supplement cereal-based food, such as maize and wheat (Uusiku et al., 2010). Hence, leafy vegetables are increasingly recognized as promising contributors to human nutritional needs, which arecapable of supply both macro and micro-nutrients besides their bioactive compound bene-fits (Joshi and Verma, 2020).

The research focus on Amaranthus spp. has been rapidly expanding, and many reports have been published, especially on the grain's amaranth [97,109]. Several studies focused on different aspects, such as botanical, agrotechnological, bio-logical, chemical, and technological, and nutritional composition properties (Xu and Sun, 2001). In Africa, the cultivation and consumption of indigenous leafy vegetables such as Amaranthus species are highly dependent on factors such as poverty status or degree of urbanization. This is because poor families tend to consume cheap leafy vegetables more than wealthy families; hence, Amaranth is considered as the poor man's vegetable since it is one of the less expensive leafy vegetables in the markets (Achigan-Dako, Sogbohossou and Maundu, 2014). In Sub-Saharan Africa, important nutrients are lacking in the staple diets of most of the population because their diet mainly consists of maize, sorghum, rice, and cassava. These crops do not take up zinc while growing, and therefore, cannot provide it in the diet. Hence, they must be supplemented (Rastogi and Shukla, 2013; Achigan-Dako, Sogbohossou and Maundu, 2014). Furthermore, several African countries have used Amaranthus as an important dietary supplement for those infected with HIV/AIDS.

Thirteen species of Amaranthus were found to have been documented as commonly found in the Western part of Africa, precisely in Nigeria under cultivation, either as weeds or ornamental. Although none of the thirteen species is of Nigerian origin, most have since adapted to the climate and are valued for their leaves, herbaceous stem, inflorescence, seeds, and chemical byproducts (Chidozie Ogwu, 2020). In West Africa, Nigeria, Amaranths are mostly considered vegetables with great potentials. The leaves, the stems are utilized in potherb, salads, burgers, and soup or stew. Amaranthus is cheap; hence it has been a preferred choice for many. It is also preferred because it can supplement the diverse cereals and legumes, which make up the bulk of daily food (Chidozie Ogwu, 2020). The most common mode of utilizing Amaranthus species in Africa, for example, in Nigeria, is to cook the leaves like spinach. The leaves are also added toa mixture of salads (Chidozie Ogwu, 2020). West Africans value the leafy amaranths more than the grain species, perhaps because of the limited information on whether the seeds are edible not. However, the leaves are collected during the growth cycle when the nutrient is at its peak and are mixed with condiments to make soup. At the same time, the stems are also preferred fresh and succulent. The grain amaranths are underutilized in Nigeria despite their potential to contribute to food security and livelihood. They are also used as ornamentals to decorate parks, domestic and office complexes (Chidozie Ogwu, 2020).

In South Africa, poor households tend to use traditional leafy vegetables, especially Amaranthus, more than their wealthier counterparts. This is simply be-cause traditional vegetables, such as Amaranthus, are cheaper in terms of money, accessibility, and even cultivation than exotic vegetables, which are expensive (Jansen van Rensburg et al., 2007; Chidozie Ogwu, 2020). Therefore, using wild food, such as Amaranthus, forms part of the safety measure that rural dwellers use as a coping mechanism to mitigate poverty, disaster, and livelihood stresses. Similarly, consumption of leafy vegetables is highly dependent on factors, such as poverty status, degree of urbanization, accessibility to fresh produce markets, and season of the year. In South Africa, the young leaves of Amaranthus are cooked and used as vegetables (Jansen van Rensburg et al., 2007). Similarly, in the past, in Limpopo Province, South Africa, where there was difficulty in accessing salt, dried Amaranthus plants of different species have been burnt to produce ash, it is dis-solved in water, and the filtrate of the ash was used as salt (Jansen van Rensburg et al., 2007). Regionally, in Southern Africa, Amaranthus leaves are harvested by hand and are best eaten fresh, just as spinach. It is boiled in salted water and served with a sauce of tomatoes and onion or potatoes. The fresh leaves are added to salads or stir-fry and added to other cooked vegetables, such as broccoli and on-ions. In addition, a cup of boiling water could be poured on a quarter cup of fresh Amaranthus, and the infusion of Amaranthus leaves used to treat anaemia, chronic fatigue, diarrhoea as well as coughs, and heavy menstrual bleeding. Amaranth also has got other uses: in the Tzaneen area, Amaranthus spinous leaves and stems are dried, grounded, and are used as snuff (Hart and Vorster, 2005). In addition, a cooled tea of Amaranthus can be used as a lotion to relieve itchy burning skin and is used to clean wounds (Louw, 2020).

Most Amaranth species consumed appeared to be of the wild species. Very few are grown, which fall within leafy types that are most common in markets of tropical Africa. Although Amaranthus also has been grown for their seed's purposes, in the continent, however, they include those varieties of American origin, and many do not utilize their seeds (Wu et al., 2000). There is an increased pro-duction and consumption of leafy vegetables in Rwanda, Uganda, Malawi, and Tanzania (Achigan-Dako, Sogbohossou and Maundu, 2014). Another important project was the Diversity International's African leafy vegetable program con-ducted in Botswana, Cameroon, Kenya, Senegal, and Zimbabwe, which induced notable changes in growing, consumption, marketing, and nutritional awareness of African leafy vegetables, including Amaranths (Gotor and Irungu, 2010). There are still gaps in the knowledge of some popular Amaranthus in Africa, resulting in complexities and confusion in the species' nomenclature and their nutritional composition (Grubben and Denton, 2004). Moreover, there is limited information on the breeding potentials, especially of the wild species, that can be promoted for sustainable utilization, especially among the rural communities (Achigan-Dako, Sogbohossou and Maundu, 2014). Interventions have been carried out by partnerships between research institutions and local NGOs to promote indigenous vegetables, including Amaranthus. A typical example of a project led by the World Vegetable Centre was centred on the promotion of neglected indigenous vegetable crops for improved nutrition and health in Eastern and Southern Africa (Achigan-Dako, Sogbohossou and Maundu, 2014). The leafy Amaranthus is the most commercialized in tropical Africa (Wu et al., 2000; Achigan-Dako, Sogbohossou and Maundu, 2014). The acceptability, utilization and commercialization of Amaranths could be improved since research are on the rise, creating more awareness that could promote its usefulness, accessible strategy, and utilization (Achigan-Dako, Sogbohossou and Maundu, 2014).

2.11 Problems Associated with Production and Underutilization of *Amaranthus*

Many underutilized vegetables, including Amaranthus surfers, neglect because of a preference for exotic vegetables, which affects Amaranthus production and its utilization (Mayekiso, Taruvinga and Mushunje, 2017). Also, there is an increased transition of the dietary lifestyle of people to fast food, which affects the utilization of traditional vegetables because it appears the younger generation prefers most fatty, sugary, salty tastes associated with many snacks and fast foods (Taleni and Goduka, 2013). The methods of preparation and other complementary ingredients used during cooking might also be a problem for consumers. Hence, a more novel method of preparation of Amaranthus-based food products is suggested. In the same vein, the negligence could also be attributed to people’s perceptions and preferences [115,116]. The loss of the traditional food knowledge system due to social changes have been recorded in Africa as a factor for the un-der-utilization of most traditional vegetables, including Amaranthus (Mayekiso, Taruvinga and Mushunje, 2017). People’s attitudes and perceptions are identified as contributing factors to the neglect of many traditional vegetables, including the wild varieties of Amaranthus, which has been considered as pig feeds; hence it is under-utilized. However, Amaranthus is reported as an edible plant and a valuable source of nutrients for the optimum wellbeing of both humans and animals aside from other uses (Rastogi and Shukla, 2013).In addition, when Amaranthus is grown on nitrogen-rich soils, which may concentrate nitrate in the leaves or any tissue of the plant. Nitrates may contribute to stomach cancers, blue babies, and other health problems (Alegbejo, 2014). This is because Amaranthus is a plant that has a high chance to accumulate nitrates, especially when soil fertility is very high. Worst is when nitrogen fertilizer is added, and if things like herbicide, drought, or frost slow the processes of photosynthesis, Nitrates can only concentrate mainly in the plant tissues and not in the seeds (Alegbejo, 2014). Interestingly, humans and some animals have bacteria in their digestive systems that convert nitrates to nitrite; such that by six months of old in humans, the acid levels in the digestive system rise higher; hence it kills these bacteria, and the danger of nitrate poisoning is unlikely, to occur. However, there is an increased risk if a pregnant woman with low stomach acidity is being treated for cancer (Alegbejo, 2014). Therefore, it advisable to eat this plant if it is grown on natural land where chemical fertilizers are not used. Poor cultivation practices of plant foods may predispose the consumer to some health risks of nitrates and oxalates and possible contamination with toxic materials like lead, resulting from the poor cultivation practices or pollution, which can contribute to its underutilization (Onyango et al., 2008).

2.12 Nutraceutical and Healing Potentials of *Amaranthus*

Nutraceuticals properties are the non-specific biological agents that boost and promote well-being. It conserves as a preventive measure to malignant processes and controls the symptoms of illnesses (Manikandaselvi and Nithya, 2011). The wild species Amaranthus *viridis* and spinosus have been investigated for their composition, including the medicinal and nutraceuticals properties. The Weedy Amaranthus has been identified to have remarkable protein, dietary fibre, carbohy-drates, Fe, Ca, Zn, K, Mg, P, S, Mn, Cu, Na, chlorophylls, β-cyanins*, β-xanthins, betalains*, β-carotene, vitamin C, compared to other cultivated species.

Both seeds and Amaranthus leaves are highly nutritious for human consumption. It promising to meet the nutritional need hence can be explored as a food plant with an added advantage that can either be explored for its preventive or curative purposes. Several studies report that Amaranthus seed, or oil may benefit those with hypertension and cardiovascular disease; hence, its regular consumption reduces blood pressure and cholesterol levels while improving the nutritional value of essential micro-nutrients, including β-carotene, iron, calcium, vitamin C, and folic acid (Priya et al., 2007; Achigan-Dako, Sogbohossou and Maundu, 2014; Alemayehu, Bendevis and Jacobsen, 2015). The leaves have great potential for pro-vitamin A carotenoid (β-carotene), which are boosters of immunity. For ex-ample, the amino acid profile of Amaranthus *cruentus* leaves includes appreciable methionine niacin and lysine levels, which are the limiting amino acids in most plant proteins (Achigan-Dako, Sogbohossou and Maundu, 2014). Also, the seed, leaves, stem, and root carotenoid content of Amaranthus *cruentus* was investigated, and the leaves were found to be highest in β-carotene (Alercia, 2013). Currently, it appears Amaranthus is advancing to be a new millennium crop with nutraceutical value. The major carotenoid identified in Amaranthus leaves canthaxanthin, which is an anticancer agent, other carotenoid includes β-carotene and lutein, an active nutrient essential for the prevention of age-related eye diseases (Venskutonis and Kraujalis, 2013; Peter and Gandhi, 2017). Amaranthus is rediscovered as a prom-ising plant with the potential to provide high-quality protein, unsaturated oil (Venskutonis and Kraujalis, 2013). Amaranthus leaves are a great source of proteins and micro-nutrients, including iron, calcium, zinc, vitamin C, and vitamin A and B vitamins. Even though studies on the leaves of Amaranthus are limited, in Africa, leafy Amaranthus vegetables provide many rural households with food, especially in the summer and winter seasons (Achigan-Dako, Sogbohossou and Maundu, 2014). There is usually sudden rise of food prices during the winter season, hence, most households fall back to traditional vegetables, such as Amaranthus. Hence, it forms the basis of nutrition in most rural households, and it is contributing up to about 80% of their total food supply, excluding the maize component of food used in winter. This dilemma is evident among communities with high unemployment issues, especially where children no longer qualify for social grants like child support grants. Thus, low-income earners tend to be more reliant on traditional vegetables. This substantiates a link between Amaranthus and poverty, as reported in recent scientific studies (Achigan-Dako, Sogbohossou and Maundu, 2014; Wong, 2014).

Several studies have shown that oil is being extracted from Amaranthus, both the seed or oil can benefit those with cardiovascular disease, including hypertension, the regular consumption of Amaranthus reduces blood pressure, cholesterol levels, improves the antioxidant status and immune parameters that optimum wellbeing. In Benin, burnt dried Amaranthus plants are used to make potash. Vegetable Amaranthus has been used as a good source of medicinal properties that can be beneficial to young children, lactating mothers, and other patients with constipation, also fever, hemorrhage, anaemia, or kidney complaints (Rastogi and Shukla, 2013; Achigan-Dako, Sogbohossou and Maundu, 2014). In Africa, an ethanolic formulation of Amaranthus spinosus increased haemoglobin content and blood schizonticides activity, which is reported to use as an antimalarial effect compared to chloroquine (Peter and Gandhi, 2017). The paste of leaves and roots of the same species have been applied as a poultice to relieve skin diseases/disorders that include abscesses, bruises, burn, eczema, inflammation, gonorrhoea, menorrhagia, and wound (Ganjare and Raut, 2019).

Amaranthus has soporific effects and febrifuge actions, which are also used to induce sweat and to reduce fever. The boiled leaves are administered for 2–3 days to cure jaundice, some kinds of rheumatic pain, and stomachache (Khongsai, Saikia and Kayang, 2011; Peter and Gandhi, 2017). In addition, the paste of the root has been used to possess several beneficial effects when used internally and externally (Ganjare and Raut, 2019). The root paste with an equal volume of honey controls vomiting when mixed with sugar, and water controls dysentery (stools and mucus), when mixed with black pepper in ratio 1:3 proportion meaning (one-part black pepper and three parts root paste) can be administered twice daily is beneficial in Rabies (Ganjare and Raut, 2019). The entire plant of Amaranthus spinosus has been used as diuretic, purgative, refringent, and to treat cholera, piles, and snake bit (Jiménez-Aguilar and Grusak, 2017; Ganjare and Raut, 2019). A study in Kenyan, the South Coast in the Msambweni community, to be precise, where malaria is endemic, reports that Amaranthus hybridus L, a plant species, has been used traditionally to treat malaria (Peter and Gandhi, 2017).

The roots of Amaranthus can be boiled with honey and used as a laxative for infants. In Ghana, the water of macerated Amaranthus plants has been used as a wash to treat pains in the limbs. Similarly, in Ethiopia, A. *cruentus* is used as a tapeworm excellent. Moreover, in Sudan, the ash from the stems is used for wound dressing. The heated leaves are used in the treatment of tumours. Furthermore, A. *tricolor* and A. *caudatus* are used externally to treat inflammations and internally as a diuretic diet (Soriano-García et al., 2018). Moreover, the seeds of A. spinous are used as a poultice for broken bones. It is used internally to treat internal bleeding, diarrhoea, and excessive menstruation (Ganjare and Raut, 2019; Jimoh, Afolayan and Lewu, 2019). In Southeast Asia, a decoction of Amaranthus root is used to treat gonorrhea.It is also applied as an emmenagogue and antipyretic (Baral et al., 2011; Achigan-Dako, Sogbohossou and Maundu, 2014). Among the Nepalese and some tribes in India, Amaranthus spinous is used to induce abortion (Peter and Gandhi, 2017). Countries across the world considered the bruised leaves as a good emollient (Soriano-García et al., 2018). Likewise, the leaves are used for gastro-enteritis, gall bladder inflammation, abscesses, arthritis and are used to treat snakebites. In addition, the sap of Amaranthus has been used as an eyewash to treat ophthalmia and convulsions in children. Hence, these reports attest to a rise in interest in medicinal plants that have healing effects on humans. Amaranthus is a source of various phenolic phytochemicals, including rutin, *isoquercitrin*, *nicotiflorins*, to mention a few. It has tremendously been used in people's daily food and industries. In addition, these phytochemicals are used in various medical fields either as preventive and curatives to diseases (Joshi and Verma, 2020).

Interestingly, Amaranthus is enlisted among the medicinal plants, which have been explored to possess great potentials for treating several illnesses. Furthermore, ex-tracts from Amaranthus have been used for medicinal purpose in Asia and ancient Indian, Nepalese, Chinese, and Thai to treat several health conditions including urinary infections, gynaecological conditions, diarrhoea, pain, respiratory disorders, diabetes, and as a drug that increased the passing of urine (Peter and Gandhi, 2017). The root extract of Amaranthus spinous has been used as vermicide (a poisonous substance to worms), whereas the aqueous decoction/infusion of the plant is used for chronic diarrhoea in southern Odisha (Peter and Gandhi, 2017). Some tribes apply spiny Amaranthus to induce abortion. Still, on Amaranthus, the juice is used by tribal of Kerala, a state in India to prevent swelling around the stomach, while leaves are boiled without salt and consumed within 2–3 days to cure jaundice (Olajide, Ogunleye and Erinle, 2004). However, the anticancer, an-ti-viral, hepatoprotective, neuroprotective, cardioprotective and antidiabetic properties of Amaranthus with relevance to current global health scenario are currently in the public interest (Achigan-Dako, Sogbohossou and Maundu, 2014). Scientific interest in Amaranthus and its health promoting benefits has increased significantly in the recent past with various analyses presenting nutraceutical properties of amaranth (Olajide, Ogunleye and Erinle, 2004; Tatiya et al., 2007).

It is established in several studies that all parts of Amaranthus spp. are edible (Achigan-Dako, Sogbohossou and Maundu, 2014; Alemayehu, Bendevis and Jacobsen, 2015). Holistically, the plant Amaranthus is a rich source of nutraceutical, which are yet to be exploited to their maximum benefits. Although the leaves of Amaranthus are usually neglected in research, an example of a study on Amaran-thus *cruentus* was investigated for its carotenoid content in Dalmatia and, the re-port of pro-vitamin A carotenoid (β-carotene) content was interestingly revealed in the following order: Carotenoid content was identified highest in the leaves, followed by seeds, stem, and roots (Dlamini et al., 2010). The major carotenoid identified in the leaves was canthaxanthin, an antitumor agent, followed by β-carotene and lutein, which is also considered active in retarding age-related eye diseases (Dlamini et al., 2010; Peter and Gandhi, 2017).The β-carotene of A. *cruentus* in that study was seven times higher than in tomatoes, which may help to treat anaemia in African countries (Dlamini et al., 2010; Peter and Gandhi, 2017).

In addition, A.*spinosus* have been reported to have higher calcium content in the dry leaves, followed by A.*tricolor*, A. *viridis*, and A.*blitum*, while iron content was rated highest in

A.*viridis* followed by A.*spinosus*, A.tricolor, and A. *blitum*. This implies that Amaranthus spp. can be explored as a source of biogenic calcium and in antacid preparations (Srivastava, 2011).

Amaranth grain, commonly known as *Rjgira*, in India, has been identified as highly nutritious and a good source of bioactive compounds such as anthocyanins and polyphenolics. Furthermore, the grain has been noted for its high protein content, with complete essential amino acids and substantial lysine as unique compared to other grains. Besides, it is known for quality starch, oil, fibre, vitamins (A, K, B6, C, E, and B), and essential minerals like calcium, iron, etc. (Peter and Gandhi, 2017) It also have advantages that can be explored as a food supplement since it is gluten-free with a high content of quality protein and unsaturated fatty acids. Grain Amaranthus is a rich source of fibre and an alternative natural source of squalene (a triterpene), a superior antioxidant ever identified for its wide biological efficacy; against cancer (Ronco and De Stéfani, 2013) Hence, Antioxidants, molecules with the reducing effect of free radicals vital for protection against cancer and degenerative disorders, are in abundant Amaranthus spp. (Peter and Gandhi, 2017). The antioxidant potential of Amaranthus has been credited to the presence of appreciable levels of phenolics and flavonoids. The leaves and flowers of Amaranthus and their extracts have been investigated to possess the highest antioxidant activities compared to other dietary rutin supplements (Peter and Gandhi, 2017). Amaranthus. is identified to contains nutraceutical elements when com-pared with the exotic vegetables. An example of Amaranthus nutritional value compared with an exotic vegetable is described in Table 4, where it has been identified to have an appreciable amount of nutrients, hence it can be included in the diet more as a daily nutritional supplement for addressing malnutrition diseases. The inclusion of Amaranthus in diet especially the staple foods, can boost immunity and optimize well-being.

Table 2-4: Nutritional value of raw and cooked (boiled and drained without salt) amaranth leaves compared with raw cabbage Source [3]

Nutrient/Leafy Vegetable	Raw	Cooked	Cabbage
Protein	1.2	2.11	1.28
Calcium	40	209	40
Iron	0.47	2.26	0.47
Magnesium	12	55	12
Phosphorus	26	72	26
Potassium	170	641	170
Manganese	0.160	0.861	160

Vitamin C	36.6	41.1	36.6
Riboflavin	0.04	134	0.04
Niacin	0.234	0.658	0.559
Vitamin A	5	139	5

2.13 Conclusions

Amaranthus has been identified as an underutilized vegetable with great potential to supply the dietary needs of animal and humans. Although Amaranthus is low in calories, its protein, fat, and fibre, as well as essential vitamins and minerals, are considered to alleviate malnutrition and optimize well-being. Amaranthus can play a significant role in the food and nutrition security of vulnerable groups in urban and rural settings. Amaranthus has been rediscovered to have medicinal, nutraceutical, industrial, and ornamental benefits, which cannot be overemphasized. Currently, Amaranthus is considered as one of the most produced and consumed indigenous vegetables on the African continent with high nutritional potentials, which are yet to be explored. The potential and use of traditional vegetables (Amaranthus) varieties in America, Asia, and Africa has been reviewed and, the cultivation of Amaranthus, commercialization and processing of the leaves to powder is still at a low level. Suitable production systems, innovative processing, and novel value-adding techniques that may promote utilization of Amaranthus are lacking. Similarly, education about Amaranthus nutritional benefits and the pro-vision of good packaging and storage is needed. The addition of Amaranthus as an ingredient in indigenous foods could enhance the utilization of Amaranthus at the community level which can improve the food and nutrition security of population with nutrient deficient challenges and could also make Amaranthus a viable commercial food product for improved livelihood of many, especially the under-privileged.

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CHAPTER 3: MATERIALS AND METHODS

3.1 Introduction

This study explores an underutilised vegetable (*Amaranthus dubius*) as a potential food ingredient to enhance the nutritional content of wheat flour *Ujeqe* (steamed bread) for prevention and alleviation of food and nutrition insecurity, which is a forerunner to malnutrition (Olusanya, 2018). Although *Amaranthus* is identified as an underutilised crop, it is considered as a food-based approach that is a cost effective and sustainable measure for curbing malnutrition, especially among vulnerable groups (Achigan-Dako et al., 2014; Aderibigbe et al., 2022). Thus, in this study, *Amaranthus* leaves were sourced from a local market in the study area, processed into *Amaranthus* leaf powder (ALP), and ALP supplemented *Ujeqe* was developed in varying percentage (0%, 2%, 4% and 6% ALP) *Ujeqe*. The results are described in Chapter 6. This chapter describes the research methodology of the study, the study area, the conceptual framework, data collection tools, the techniques employed, and the rationale for the choice of method for the study.

3.2 Conceptual framework

The conceptual framework of this study was adapted from Khoza *et al.* (2014) and Young, (2020). The framework revolves around malnutrition; the underlying causes, and especially its immediate causes which are rooted in a compromised dietary lifestyle where the less-privileged over-rely on a monotonous diet of starch-based and cereals-based sources. Nutrient dense vegetables are considered as a functional food with suitable nutrients. *Amaranthus* is an underutilised crop, even though it has the potential to address malnutrition and other nutrient related health challenges such as micronutrient malnutrition.

The immediate cause of malnutrition is related to food, thus, tackling this challenge demands a measure that addresses the challenge at the household level. A continuous focus on prevention of malnutrition, especially micronutrient malnutrition, via a food-based approach which encourages diversification in nutrition, has been identified rather than only management of malnutrition's health challenges.

The pillars of food security are aimed at all people always having access to safe and nutritious food for an active life (McDonald, 2010). South Africa seems to be a food secure nation, but inadequate consumption of nutrient-rich foods is still a salient factor that leads to food-related deficiency problems at the household-level (Dukhi, 2020). Malnutrition, especially micronutrients deficiency is a global health challenge that is linked with nutrient deficiency issues which still occur among the less privileged who are residents in rural communities and informal settlements in many parts of the world, including South Africa (Qumbisa, Ngobese and Kolanisi, 2020; Young, 2020). The conceptual framework of this study (Figure 3.1) presents *Amaranthus* as an underutilised food plant that can be explored to prevent the prevalence of, and alleviate the nutrient-related health challenges of, malnutrition (Olusanya et al., 2021).

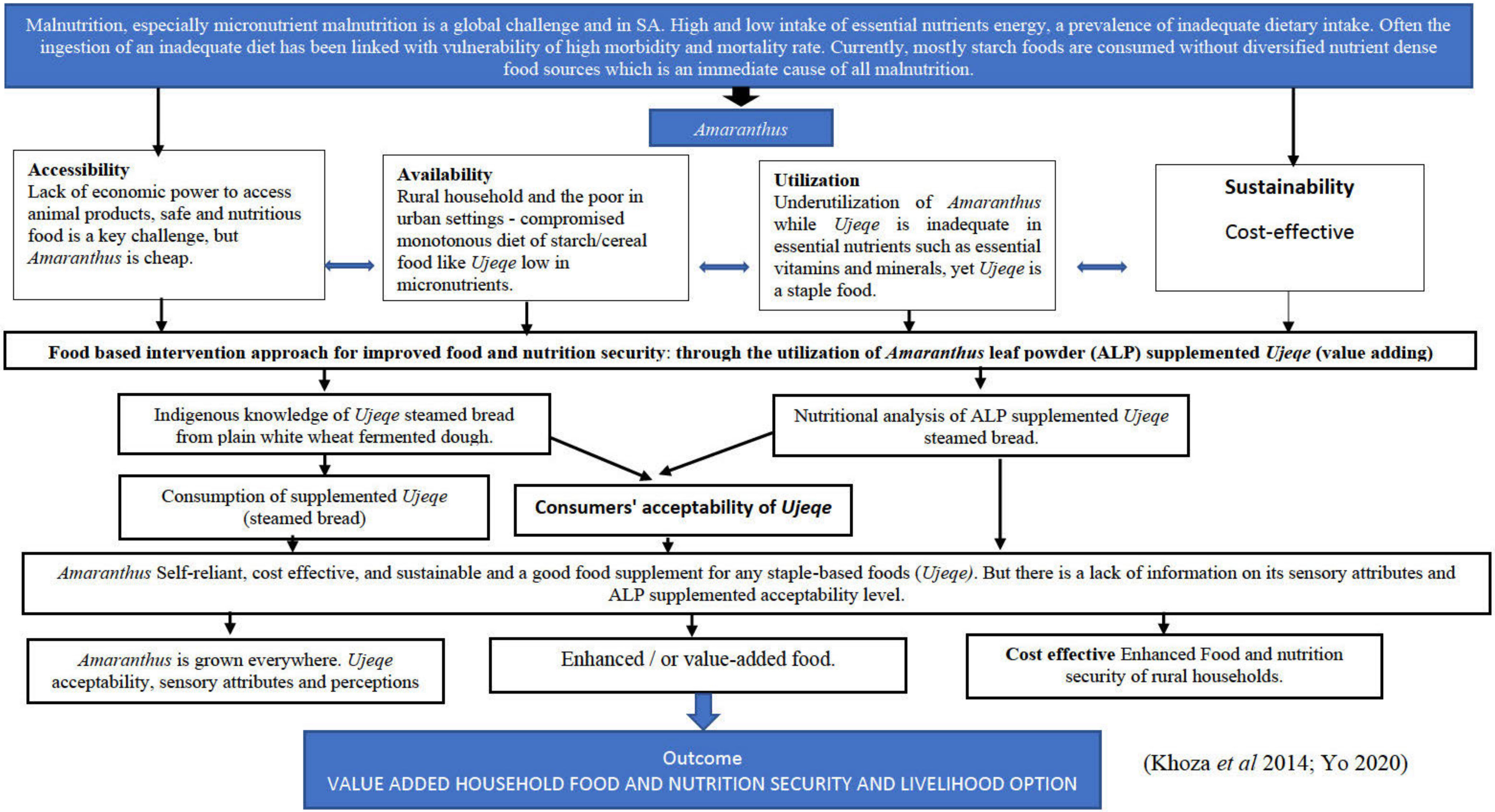

Figure 3-1: Conceptual framework of *Amaranthus* utilization to ameliorate food and nutrition insecurity

3.3 Research approach

An integrated or mixed methods approach was adopted for this study (Table 3.1). This includes quantitative and qualitative research methods otherwise considered as an exploratory and descriptive study. A mixed method is necessary because a single approach cannot proffer substantial solutions to the research problem under study (Acharya et al., 2013). This type of research approach is pragmatic and combines both qualitative and quantitative approaches of investigation in different stages of the research procedure. This research design appears to be the most widely used approach both in science and social sciences (Terrell, 2012). The researcher found this technique appropriate for this study because the study involved both field work (survey) and laboratory work where a systematic approach was needed to provide a scientific approach and make fair judgment for the purpose of food and nutrition security of all people. This study was aimed at identifying the most consumed variety of *Amaranthus*, evaluating it along the value chain, then processing the leaves of one of the commonly grown and consumed *Amaranthus* into powder for the development of ALP supplemented *Ujeqe* .

Quantitative (experimental) research is designed to establish a statistical measure to make a significant conclusion about a certain population. Experimental research is a type of research that requires some form of an intervention with participants or testing materials (samples) under controlled conditions, usually with inclusion of a control group. This research design uses a representative sample of the population, the population being the entire group being studied. In this situation it does not matter if the population is broad or narrow, only that every participant fits into the description of the group being studied (Creswell, 2003; Creswell, 2011).

In this study, the most consumed *Amaranthus* was utilised to enhance conventional *Ujeqe*. Thus, *Ujeqe* was supplemented with *Amaranthus dubius* leaf powder and was considered as a form of intervention to improve the nutritional quality of *Ujeqe*. The developed samples were measured against a control sample measuring the same attributes.

A qualitative research approach was also followed in this study. Qualitative research is designed to describe a clear event/idea in its own natural settings and is a subjective way of looking at life as it is lived while explaining the studied behaviour. In this approach, representative samples and well-structured data collection methods were followed, and a descriptive research design was used to obtain a picture of the rural community's perceptions and ideas and opinions on the entire value chain of the most consumed *Amaranthus* variety and utilisation of *Ujeqe* (Creswell, 2003; Lowhorn, 2007).

Table 3-1: Research design

RESEARCH APPROACH	**RESEARCH DESIGN EXAMPLE**	**JUSTIFICATION**	**ACTION TAKEN**	**SAMPLING TECHNIQUE**
Qualitative	**Exploratory study**	Exploratory study is a type of research design that explores a research question that has not been studied or of which the researcher has limited knowledge and understanding. An exploratory research design was chosen because the researcher wanted to have knowledge and understanding of the topic of the study. Also, this design helped to provide the opportunity to investigate the research questions that were to be explored.	Online search of materials such as e-books and journals and articles to gain insight. Preparation of a review paper (Chapter 2) on the underutilisation versus nutritional-nutraceutical potential of *Amaranthus* (published).	Secondary data was collected and reviewed in the literature review presented in Chapter 2 of this thesis. The review was on the general outlook of the underutilisation versus nutritional-nutraceutical potential of the *Amaranthus* food plant. As part of the sampling technique the uses of *Amaranthus* in Asia, America and Africa were reviewed as these are some of the places where *Amaranthus* has been domesticated.
	Descriptive approach	Descriptive research describes the characteristics of the population or phenomenon under study. It is more of an observational research method that has no influence on the variables. The nature of the variables or their behaviour is not in the hands of the researcher.	A **survey** study was conducted in the study area which was further complemented by face-face interviews with total of n = 6 key informants who were vegetable supervisors and vendors in the open markets and informal markets in the study area. 100 structured questionnaires were administered to collect data to gain insight on the utilisation and consumption pattern of *Ujeqe* and *Amaranthus.* The results obtained are presented in Chapters 4 and 5.	Purposive technique, convenience random sampling.
Experimental	**Quantitative**	Quantitative research involves manipulating quantity to determine the effect on the outcome of the variables. The reason this approach was used is because measurement of ingredients and quantities was involved in the study.	Nutrition analysis: proximate analysis and minerals of raw materials, namely, plain wheat flour (PWF) and *Amaranthus* leaf powder (ALP). Also, the physical properties of the formulated bread samples were analysed i.e., loaf weight, loaf volume and loaf specific volume.	Appropriate quantities of the food samples were analysed in triplicate according to the AOAC technique by CIDARA.

Experimental	**Qualitative**	Sensory evaluation was conducted during the research. This method was chosen to describe the organoleptic parameters of the ALP-supplemented *Ujeqe* samples using the 5-point pictorial hedonic scale (smiley face).	60 untrained panellists were used to describe the sensory properties of the formulated *Ujeqe* samples, namely, colour, taste, texture, aroma, mouth feel and consumer acceptability.	Random sampling technique was used to select 60 panellists in the eMpangeni community.

3.4 Population sampling of target population

A total of 100 participant were selected to capture data for the survey study which is presented in Chapter 5 of this study. Six key informants were purposively sampled for face-to-face interviews from selected malls and open markets across the study area as reported in Chapter 4. Monotonous diets that are starch-based is a critical issue in many sub-Saharan African countries including Africa. This dietary kind of lifestyle is more common among rural communities where malnutrition still lingers. Hence the need for increased use of underutilised vegetables like *Amaranthus* which can expand the rural population food basket, thereby diversifying their diet (Emmanuel and Babalola, 2022). Sixty (n = 60) untrained panellists were randomly selected from a rural community for sensory evaluation of ALP supplemented *Ujeqe* prototypes as reported in Chapter 6.

3.5 Description of the study area

The study was conducted in in Empangeni in the province of KwaZulu-Natal, a town that is 160 km away from Durban along the R34 off the N2. The town is positioned in the hilly countryside of the uThungulu district. The surrounding environs of eMpangeni is known as a centre for cotton, cattle, timber and sugarcane. It is only 15 km away from Richards Bay on the coast, and these two towns, together with Vulindlela, Esikhawini, Felixton, Nseleni, and Ngwelezane, make up the city of uMhlathuze. eMpangeni was originally the location of a Norwegian Mission station founded near the stream called eMpangeni, which was later moved to Eshowe. The name Empangeni, according to folklore, comes from a Zulu word known as ‘pangaed’, which means ‘grabbed’, and is thought to refer to the number of crocodile attacks on water bearers in the nearby Empangeni stream. The geolocation of eMpangeni is -28°44'50.3868",31°54' 42.7078"(SAHO, 2017). Besides eMpangeni rural community, information regarding the most commonly variety of *Amaranthus* sold in formal and informal markets in the urban location of Durban, KwaZulu-Natal province, was collected.

3.6 Sampling method and sampling size

A 'sample' of an investigation means a subset of the population which is selected to be a representative of the larger population for a particular study because a large population is difficult to study (Acharya et al., 2013). Sampling techniques are broadly classified as 'probability' and 'non-probability' techniques (Robinson, 2014). A probability type of sampling technique allows the principal investigator to generalise the findings of the sample to the target population. Probability sampling includes simple random sampling, systematic random sampling, cell sampling, stratified random sampling, cluster sampling, quota sampling, and single-case selection strategy etc. (Acharya et al*.*, 2013; Robinson, 2014).

In this study, a purposive convenience random sampling method was used to recruit participants for the survey aspect of the study which sought to gain insight into the value chain among the informal and formal marketers of *Amaranthus.* Purposive convenience sampling is described as an intentional choice of a participant based on the qualities or criteria that the participant possesses. Using this sampling technique, the researcher decides what needs to be known and sets out to find people who can and are willing to provide the information due to their knowledge or experience (Ehrlich and Harte, 2015). These research methods are cost and time efficient. The informal market (*Amaranthus* vendors) and malls that sell food including leafy vegetables were the targeted population, categorised according to formal and informal market social status of most people who patronise them. To obtain the right information regarding *Amaranthus,* key informants were selected for interviews, being supervisors for the vegetable sections of the malls. They included low-class, middle-class, and upper-class malls. The final sample population included the major malls (three low class, three middle class and three upper class). A total of n = 18 formal markets were randomly selected as a sample of the survey study: nine in Empangeni and the nine in Durban. A total of n = 60 untrained panellists was recruited during the survey. Invitations were sent out to the identified participants as a reminder to attend the sensory evaluation exercise.

3.7 Population sampling of target population

A total of 100 participant were selected to capture data for the survey study which is presented in Chapter 5 of this study. Six key informants were conveniently sampled for face-to-face interviews from selected malls and open markets across the study area as reported in Chapter 4. Monotonous diet is a critical issue in many sub-Saharan African countries which includes South Africa. This kind of diet is more common among rural communities where malnutrition still lingers. Hence the need for increased use of underutilised vegetables like *Amaranthus* which can expand the rural population's food basket, thereby diversifying the diet (Emmanuel and Babalola, 2022). Sixty (n = 60) untrained panellists were randomly selected from a rural community for sensory evaluation of ALP-supplemented *Ujeqe* prototypes as reported in Chapter 6.

3.8 Product development of *Ujeqe* (steamed bread)

Amaranthus leaf powder supplemented *Ujeqe* was developed by substituting ALP at varying percentage (0%, 2%, 4% and 6%). The nutritional analysis was conducted according to the AOAC Official Methods (AOAC 2003). The processing of *Amaranthus* into leaf powder and the development of the supplemented *Ujeqe* is fully described below.

3.9 Sources of materials, equipment used to produce ALP supplemented *Ujeqe.*

The *Ujeqe* ingredients for this study were purchased from Shoprite at Esikhawini Empangeni, South Africa. The ingredients were Golden Cloud white bread wheat flour, sunflower oil, Hulletts white sugar, Gold Star instant yeast (finest quality), and iodised sea salt. All ingredients were stored separately in an airtight storage box in a refrigerator (4°C) until they were used. *Amaranthus dubius* leaves were purchased from local vendors at the station market in Empangeni, KwaZulu-Natal, South Africa. They were processed into ALP according to the description in Figure 3.3 The equipment used in this study included a Combi-master oven fan, dryer, and electric stove, 0.05 mm sieve, stainless steel colanders, electric blender (Wz-Q10S, multifunctional speed blender), medium stainless-steel pot, stainless steel bowls, digital weighing scale, foil paper, aQuelle natural spring still water, ceramic bowls and saucers, serviettes, disposable cups, and five-point pictorial smiling face hedonic scale as described in the Appendix.

Amaranthus dubius leaves as shown in Figure 3-3 were sorted, graded, and washed thoroughly under running tap water. This whole process of sorting and grading eliminated the dirt that came with the *Amaranthus* leaves. To get rid of contaminants from agricultural processes that may come along with the *Amaranthus* leaves, two teaspoons of salt were dissolved in 2L of tap water. This water was used to wash the *Amaranthus* leaves, after which the leaves were rinsed thrice to remove any excess salt (Qumbisa et al., 2020). The washed *Amaranthus* leaves were placed in a strainer for a few minutes to drain the excess water, after which the *Amaranthus* was dried in a combi oven fan dryer at 70°C for 2 hours(Qumbisa et al., 2020). The dried leaves were milled into a fine powder using an electric blender. To obtain a uniform ALP, the ground ALP was sieved through a sieve of 0.05 mm, after which it was packed into airtight, labelled zip-lock plastic bags until it was used for the production ALP-supplemented *Ujeqe*.

3.10 Production of *Amaranthus* leaf powder

The *Amaranthus* leaf powder was self-processed following the procedure in the next subtopic described in the flow chart diagram in Figure 3-2, as describe by Qumbisa (2021).

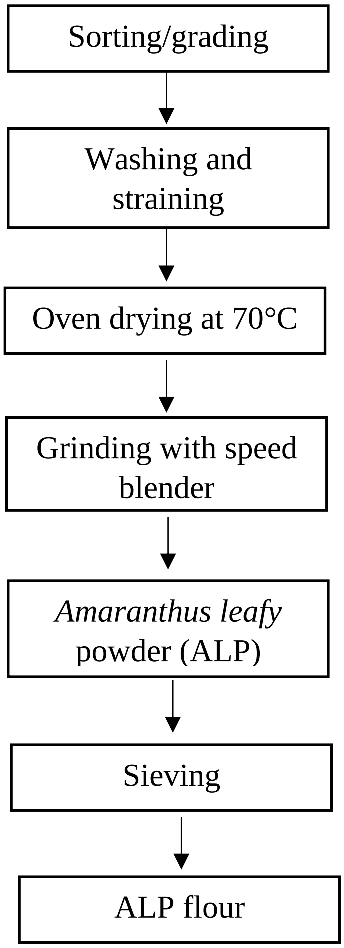

Figure 3-2: Flow chart for processing of *Amaranthus dubius* leaves to *Amaranthus* leaf powder (ALP)

Figure 3-3: Cleaned *Amaranthus dubius* used for processing of ALP

3.11 Production of standardised *Amaranthus* leaf powder supplemented *Ujeqe*

An experiment was conducted to establish the effect of ALP on the mineral composition and consumer acceptability of *Ujeqe*. The ingredients in Table 3-2 were used to formulate a composite flour for ALP-supplemented *Ujeqe* prototypes. ALP was substituted for plain wheat flour at ratios of 0%, 2%, 4%, and 6% and mixed with other ingredients and lukewarm water to formulate the dough as described in Figure 3-2.

Table 3-2: Formulation of wheat-based composite flour for controle and the development of ALP supplemented *Ujeqe*

Amaranthus %	PWF (g)	Yeast (g)	Sugar (g)	Salt (g)	Sunflower Oil (ml)	Water (ml)
0	100	3	10	1	7.5	60
2	98	3	10	1	7.5	60
4	96	3	10	1	7.5	60
6	94	3	10	1	7.5	60

3.12 Production of *Amaranthus* leaf powder supplemented *Ujeqe* (ALPSU)

The control sample (0% ALP) *Ujeqe* in Table 3-2 was prepared according to the traditional method adopted from the study site. Likewise, a standard recipe for ALP-supplemented prototypes was achieved after several trials of formulations in the food laboratory of the Consumer Science Department at the University of Zululand, Kwadlangezwa. The standardised recipe for the control sample and the ALP-supplemented *Ujeqe* recipe are presented in Table 3-2. The development of the *Ujeqe* food product started with the formulation of a composite flour based on the 0% and ALP-supplemented percentages. All the dry ingredients required were measured into a bowl to obtain a composite flour. Lukewarm water was added to the blended flour to make an elastic soft round moulded-shaped dough (6%, 4% 0% and 2%) (Figure 3A). The dough was manually kneaded for 7 minutes, after which it was covered with a kitchen napkin and was allowed to ferment (prove) for 40 minutes. The fermentation or proving was ascertained as having completed when the dough doubled in size. The *Ujeqe* fermented dough was punched to release the air from pockets in the dough, after which the dough was moulded into a ball again and placed in a stainless-steel bowl used for the steaming of the *Ujeqe*. The bowl was covered with a kitchen napkin and allowed to prove a second time for another 40 minutes. Finally, the bowl was inserted into a large stainless-steel pot of boiling water, and the *Ujeqe* dough in its pot was placed into the pot. The dough was not in direct contact with the water. Foil paper was used over the pot before the lid was placed onto the bigger pot, in order to trap the steam. The dough was allowed to steam for 50 minutes on an electric stove. The pot was not opened until 30 minutes after the stove was switched off. A skewer was inserted to check if *Ujeqe* was cooked, and a well-cooked *Ujeqe* was determined when the skewer was inserted and came out clean. The ALP supplemented *Ujeqe* samples are shown in Figure 3-5. ALP *Ujeqe* was kept at room temperature to cool for one hour, after which it was thinly sliced and spread on trays and dried at room temperature The dried slices *Ujeqe* crushed into a crucible, were packaged into a labelled zip-lock bag, and stored for 48 hours before analysis.

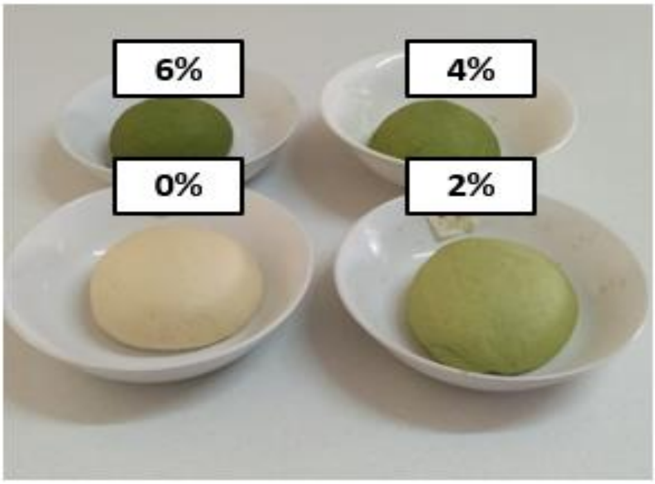

Figure 3-4: ***Ujeqe*** **dough obtained for the control and supplemented prototypes**

The 0% dough is plain wheat flour for the control sample; others are ALP supplemented prototypes 2%, 4%, and 6%.

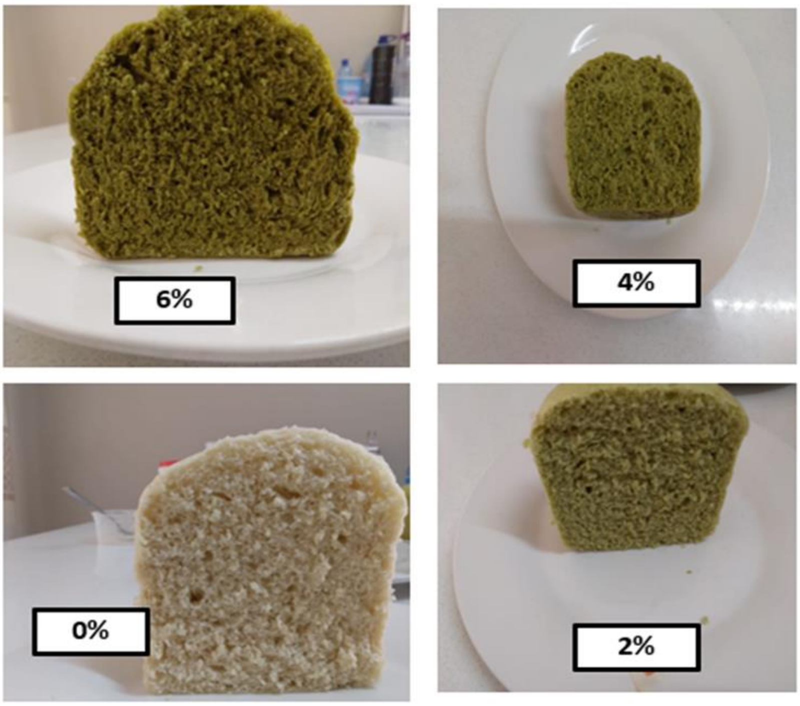

Figure 3-5: ALP 0%, 2%, 4% and 6% ALP-supplemented *Ujeqe* prototypes

3.13 Specific volume determination of ALP supplemented *Ujeqe*

Specific volumes of the *Ujeqe* were measured by the method described by Wang and Jian, (2022). The specific volumes were measured by dividing the volume by the weight. Thus, specific volume = volume / weight (cm^3/g) (Wang and Jian, 2022).

3.14 Proximate analysis of ALP *Ujeqe* food samples

The weight loss of the samples was used to calculate the moisture content, and the following equation was used to calculate the moisture content percentage:

$$\% \boldsymbol{Moisture} : = \frac{(mass\ of\ the\ sample\ +\ dish) - (mass\ of\ sample\ +\ dish\ after\ drying)}{(mass\ of\ the\ sample + dish) - (mass\ of\ petri\ dish\ without\ the\ lid)}\ x\ 100$$

Fat: The fat content of the samples was determined based on the Soxhlet procedure, using a Büchi 810 Soxhlet Fat extractor (Büchi, Flawil, Switzerland) according to the AOAC Official Method 920.39 (AOAC 2003). Petroleum ether was used for extraction. The percentage of crude fat was calculated using the following equation: -

$$\% \, crude \, fat = \frac{Beaker + fat - Beaker}{sample \, mass} \times 100$$

Protein: -The content of protein in the samples was measured, using a LECO Truspec Nitrogen Analyzer (LECO Corporation, St Joseph, Michigan, USA) according to the AOAC official method 990.03 109 (AOAC, 2003). The reference and supplemented samples were done in triplicate and placed into a combustion chamber at the value of 950°C with an autoloader. The following equation was used to calculate the percentage of protein in the samples: $\% \, crude \, protein = \% \, N \times 6.25$.

Ash: - All the mineral content of the samples was determined as ash according to the AOAC official method 942.05 (AOAC, 2003). The samples were weighed and placed in a furnace at 550°C overnight. Minerals remained as a residue of ash in the crucibles after the volatilisation of the organic matter from the samples. The following equation was used to determine the percentage of ash that was found in the models:

$$\% \, Ash = \frac{(mass \, of \, sample + crucible \, after \, ashing) - (mass \, of \, pre-dried \, crucible)}{(\text{mass of sample} + \text{crucible}) - (\text{mass of pre} - \text{dried crucible})} \times 100$$

Mineral elements: - Individual mineral elements, including calcium, magnesium, potassium, sodium, phosphorus, zinc copper, manganese, and iron, were analyzed using the Agricultural Laboratory Association of Southern Africa (IALASA) method 6.5.1. The dried *Ujeqe* prototype were ashed overnight at 550°C in dry heat. The samples were dissolved in HCl, and HNO_3 was added to the samples, which were analysed using an atomic absorption spectrophotometer. The calcium and phosphorus were determined using an Analytic Jena Spekol 1300 spectrophotometer (analytic Jane AG, Achtung Germany). Iron was determined with the Varian spectra atomic absorption spectrophotometer (Varian Australia Pty Ltd, Mulgrave, Australia). The zinc with the GBC 905AA spectrophotometer (GBC Scientific Equipment Pty. Ltd, Dandenong, Victoria, Australia).

3.15 Sensory evaluation

A total of n = 60 untrained panellists who are regular consumers of *Ujeqe* were recruited to assess the consumer acceptability level of the ALP-supplemented *Ujeqe* prototypes against the control sample (Curtis, 2013; Qumbisa et al., 2021). The panellists for the sensory evaluation were chosen because they were regular consumers of *Ujeqe* (steamed bread) and were familiar with the taste of *Amaranthus* food products. The consent of the panellists was obtained using an informed consent form before the commencement of the sensory evaluation. *Ujeqe* prototypes were served on a ceramic saucer, and each panellists evaluated four samples (0%, 2%, 4%, and 6%). Sensory attributes were assessed on a five-point hedonic scale of pictorial smiling faces, with parameters of dislike very much, dislike slightly, neither liked nor disliked, like slightly, and like very much. Panellists were instructed on how to fill in the scorecards correctly. The sensory attributes assessed were colour, taste, aroma, texture, and overall acceptability. To avoid any bias, samples were assigned a unique three-digit code, and samples were served in a randomised order obtained from a table of random permutations of nine. A serviette and a cup of mineral water (aQuelle still water) was provided for each panellist. Panellists were instructed to rinse their mouths before tasting the first sample of *Ujeqe* and, after the testing each of the four *Ujeqe* prototypes. This was done to avoid interference with previous taste of any food samples. Results obtained from all parameters were then statistically analysed. All analysis was carried out in triplicate and the data was reported as means ± and standard deviation and significant difference among treatments was evaluated through analysis of variance (ANOVA)

3.16 Management and analysis of data

According to grounded theory, analysis should occur as soon after data collection as possible (Robinson, 2014). Simultaneous data collection and analysis permits a researcher to make real-time judgements about whether further data collection is likely to produce any additional or novel contribution to the study (Robinson, 2014) Therefore, immediately the data for the sensory evaluation was collected it was coded. Coding means that the variables that the researcher wanted to analyse were identified and given different attributes and code numbers which represented those variable attributes (Amerine et al., 2013; Stone et al., 2020). The codes were entered into MS Excel then into SPS and statistical analysis was carried out which is described in Table 6.6 of Chapter 6 of this the thesis.

3.17 Ethical considerations

Ethical clearance for the study was obtained from the Research Ethics Committee HSSREC/00000435/2019 of the University of KwaZulu-Natal (Appendix E). Consent forms were used for the survey and the sensory evaluation of panellists who had agreed to partake in the study.

Table 3-3: Summary of research objectives

Objectives	**Data to be collected**	**Data collection tools**	**Sampling techniques**	**Data Analysis**
To write a review paper on the underutilisation versus nutritional-nutraceutical potential of the *Amaranthus* food plant	Indigenous knowledge system and uses of *Amaranthus* in America, Asia, and Africa. Various species of *Amaranthus*. The nutritional-nutraceutical potential of the *Amaranthus* and their uses as food plant.	Online search of literature	N/A	N/A
To identify the most commonly sold/consumed *Amaranthus in* formal and informal markets of the rural communities of eMpangeni, KZN	Capturing the various species and the most popularly sold/consumed variety of *Amaranthus* in the study area and assessing the value chain.	Interview key-informants from formal and informal marketers of *Amaranthus.*	Simple random purposive sampling.	Narrative and descriptive analysis
To assess the utilisation of *Ujeqe* and *Amaranthus* for improved food and nutrition security of rural communities in South Africa.	Demographics, frequency of *Ujeqe* consumption, reasons for consumption, perceptions of the nutritional content and utilisation of *Amaranthus.*	Structured questionnaires.	Purposive convenience random sampling technique.	Descriptive statistics
To develop commonly consumed ALP supplemented *Ujeqe.*	Lab work on the processing of *Amaranthus* leaves to *Amaranthus* leaf powder, recipe, and the standardisation of the cooking quality of ALP supplemented *Ujeqe.*	Direct observations and trials of scaling up and down of recipe to obtain a standardised recipe for *Ujeqe* product development of four prototypes: the control, *Ujeqe* (0%) and the ALP supplemented *Ujeqe* (2%, 4%, and 6%) and the nutritional composition of the raw materials and the supplemented prototypes.	Three samples of ALP supplemented *Ujeqe* prototypes were developed with 2%, 4%, and 6%.	The use of SPSS where ANOVA was be used for the analysis along with descriptive statistical analysis.
To assess consumer acceptability level of *Amaranthus* leaf powder fortified wheat flour *Ujeqe.*	The consumer's sensory attributes of colour, texture, aroma, taste, and overall acceptability of ALP supplemented prototypes.	Five-point hedonic scale for the sensory evaluation exercise, ALP supplemented *Ujeqe* prototypes.	Purposive convenient random sampling recruitment of sixty untrained panelists.	Descriptive analysis of the sensory attributes in Percentage and graph.

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CHAPTER 4: DYNAMICS OF THE AMARANTHUS IN URBAN AND RURAL VALUE CHAIN IN KWAZULU-NATAL PROVINCE, SOUTH AFRICA

Abstract (*Research Chapter: On Review Process with Elsevier Journal of Botany*)

Despite many interventions to combat malnutrition, sub-Saharan Africa (SSA) falls into developing countries status where poor a standard of living and malnutrition prevails with a devastating impact on the most vulnerable group in many regions of the world. It is reported that the less privileged in rural communities, especially women within the child bearing age group, the elderly and young children across the world are considered as the most vulnerable to malnutrition problem which is emanates from food insecurity issues. For example, significant proportion of the population of Africa is unable to access the minimum adequate diet to optimise their well-being. The health implications of malnutrition are linked with undernutrition, which is a form of malnutrition that emerges due to food and nutrition insecurity which is considered as a global challenge today. Traditional vegetables, including *Amaranthus,* have been identified as cost-effective and sustainable food choices that can be explored to reduce hunger and solve food and nutrition insecurity challenges. About 65 to 70 species of *Amaranthus* exist across the globe but only a few have been grown for food. Information on the most consumed variety in Empangeni, KwaZulu-Natal, South Africa, has scarcely been documented. Thus, this study focuses on identifying the most sold/consumed species in the formal and informal markets of the urban and rural areas of the study site. A mixed-design research method, with a purposive convenience random sampling approach, was adopted. Semi-structured questions were used to conduct a series of face-to-face interview with six key informants in in each of five (n = 30) urban and rural markets. These markets were: cartegorised informal market A Chatsworth (Durban) market; morning market in Durban city; Pinetown market; Station market and Esikhawini market in Empangeni. During the interviews, commonly sold/consumed varieties of *Amaranthus* were identified. Findings revealed that even though there are about eleven species of *Amaranthus* in the province, *Amaranthus (*A.) *spinosus* variety, including A. *dubius,* and A. *cruentus* was the most sold and consumed in both formal and informal markets of the study area. However, A. *thunbergii* was seen in the informal market of the Chatsworth market in Durban . The most common varieties sold and consumed in the rural population are the red and green Amaranthus *cruentus,* Amaranthus *spinosus* including the *dubius*. Also, some of the fruit and vegetable supervisors and marketers of fruits and

vegetables section in the formal markets (malls) declared that *Amaranthus* is not in the range of their selling products the reason being that vendors sell indigenous vegetables including *Amaranthus* right at the entrance of the malls at cheap prices. This study shows that *Amaranthus* are more available in the informal markets than the formal markets. It also identified that *Amaranthus* is underutilized because of poor perception, attitudes, and lack/limited knowledge of its nutritional benefits for sustainable nutrition at the household level. Hence, promoting *Amaranthus* in formal markets (malls) may encourage or create awareness among those who do not patronis e the roadside vendors for whatever reason. Also, studies on the dietary benefits of the commonly consumed varieties can be explored for more awareness and for improved food and nutrition security.

Keywords: *Amaranthus,* A. *spinosus*, A. *Cruentus*, Formal market, informal market, Nutrition security

4.1 Introduction

Globally, and in many developing worlds including Sub-Saharan African countries, progress to address malnutrition has been investigated. However, the challenge of malnutrition and nutrient-related health problems (including micronutrient deficiency) still exists worldwide including sub-Saharan Africa and South Africa (Dukhi, 2020; Emmanuel and Babalola, 2022). Malnutrition is also prevalent in Asian countries, where the poor standard of living has a consequential impact that affects the most vulnerable group, especially those with prolonged ill health challenges whose immune systems have been lowered. The elderly, adolescents, women within the productive age, and young children who reside in rural communities and informal settings of urban centres are vulnerable to malnutrition challenges (Dukhi, 2020; Aderibigbe et al*.,* 2022). In Africa 90% of children do not meet the minimum required balanced diet meant to optimise their well-being and 60% of families in this region are unable to have the minimum of one meal a day which implies that meals are skipped because access to food is being challenged (Rickards and Shortis, 2019). It is evident that where hunger and food insecurity prevail, food and nutrition security of people will be hard to achieve, leading to malnutrition of all forms. For this reason there is a continuous search to solve the problem of malnutrition.

The increased growth rate of the global population calls for a commensurate increase in the production of foods, with attention being paid to nutrient-dense species of food crops being combined with staple foods as enhancers .

World-wide and in sub-Saharan Africa nutrient-dense species of food-plants abound, including *Amaranthus* which is underutilised even though it has been identified as having great potential to improve the food and nutrition security of vulnerable populations and achieving the sustainable development goals (SDGs), especially SDG-2 (Aderibigbe et al., 2022). The specific target of the SDG-2 is zero hunger through food security and improved nutrition and sustainable agriculture by the year 2030. Achieving food security is more ambitious than ending hunger; however, the African continent is blessed with a nutrient-dense variety of food crops, of which *Amaranthus* is one. *Amaranthus* is highly nutritious, with great essential nutrient potentials as it contains vitamins and minerals that are needed for wellbeing (Jimoh et al., 2022). The leaves of *Amaranthus* are cooked alone or with other vegetables as a complementary food for the main dish, or eaten alone, or used as a pot herb in sauces or soups. The grains are used as enhancers of staple cereals and the whole the plant is used for livestock feed (Ruth et al., 2021). In traditional medicine, the leaves of *Amaranthus* and the root are boiled and used as anti-diabetic, antipyretic, anti-snake venom, laxative, diuretic, antileprotic, anti-gonorrhoeal, expectorant, and to relieve breathing in acute bronchitis (Achigan-Dako et al., 2014; Peter and Gandhi, 2017). *Amaranthus* has anti-inflammatory medicinal properties to boost and immune the human system, and has anti-androgenic activity and anthelmintic properties (Achigan-Dako et al., 2014; Aderibigbe et al., 2022). Although, *Amaranthus* has great potential it is underutilised crops and has received little attention especially in terms of research regarding the most sold/consumed variety in the informal and formal markets along their value chain. When an underutilised crop like *Amaranthus* is given attention, awareness can be enhanced they and increase the potential of it being commercialised, encouraging its industrial and household utilisation as a way of tackling food and nutrition insecurity.

Amaranthus, especially the *spinosus* variety, has played a vital role in sustaining food security of people, because they are vegetables that are often harvested from wild and fallow lands and it is one of the cheapest indigenous vegetables compared to other varieties of traditional vegetables and exotic vegetables (Achigan-Dako et al., 2014; Aderibigbe et al., 2022). Thus, *Amaranthus* caters for the food and nutrition security of rural communities who are challenged in accessing nutritious foods of animal origin. *Amaranthus* has helped in the alleviation of malnutrition in many low and middle resource country, including South Africa (Gerrano et al., 2015; Aderibigbe et al., 2022). However, there is still confusion about the identification of the variants of the species that are commercialised and eaten, which distorts information about the commonly sold/consumed variety as well as the nutritional composition of the common alternatives. From work reported and information from its origin, *Amaranthus*, especially the grain type, has great potential when applied to staple food products. *Amaranthus* is a C4 plant and short-lived, whose origins have been traced to America (Aderibigbe et al., 2022). The plant has been domesticated in African countries. Thus, several species of *Amaranthus* in South Africa have become naturalised plants as they have been domesticated for various purposes, such as its aestatic value, for forage and for human nutrition (Achigan-Dako et al., 2014). The genus *Amaranthus* is a complex taxon with various morphological features within the existing 65 to 70 species (Achigan-Dako et al., 2014). Despite the diversity of Amaranth species, *Amaranthus* is broadly classified into two broad groups, which includes the grain type and the leafy vegetable and are cultivated across the world, including South Africa, where there are many ethnic names (Achigan-Dako et al., 2014; Aderibigbe et al., 2022). Across the rural communities, including in Empangeni KwaZulu-Natal, South Africa, *Amaranthus* is popularly called *imbuya*, and in English it is referred to as pigweed or a type of spinach (Qumbisa et al., 2020). *Amaranthus* has been grown and utilised in many countries of sub-Saharan Africa, including South Africa. Some are indigenous, while others are identified as naturalised weeds which originated from Europe and Americas. In Africa, the leafy variety are the most widely cultivated. Some of the species cultivated as edible vegetables are *Amaranthus (*A) thunbergii, A. *spinosus* L., A. graecizans L., A *deflexus* L., A., *curuentus* , A. *viridus* L. A. *hypochondriacus* , A. *caudatus,* A. *viridis* also called slender amaranth and A. *hybridus* L. (Gerrano et al., 2015).

In South Africa, *Amaranthus* is a plant that grows without being cultivated, and is a common indigenous food plant that has spread across South Africa. In other countries and regions of the world it is also considered an important traditional leafy vegetable that is appreciated for various purposes and is used as an ornamental and medicinal plant in many countries (Senyolo *et al.*, 2018; Emmanuel and Babalola, 2022). *Amaranthus* is an excellent food plant, loaded with nutraceuticals and bioactive natural protective potentials against chronic ailments; it is considered a vital ingredient in soups or sauces which accompany most staple foods (carbohydrates/starchy foods sources) (Sarker and Oba, 2019).

However, there is a research gap on the most commonly consumed/sold species in the study area, and information regarding it is necessary in order to identify it and give it more priority both in rural and urban communities (Emmanuel and Babalola, 2022). The consumption of *Amaranthus* in South Africa is as old as the history of modern humans. The Khoisan people that lived from 120 000 years ago were hunters and gatherers and their survival depended mostly on plants harvested from the wild (Senyolo, Wale and Ortmann, 2018). History reports that about 2 000 years ago the Bantu people who started to settle in South Africa collected *Amaranthus* from the natural environment (Senyolo, Wale and Ortmann, 2018). This indicated that when other crops failed or the livestock herds were destroyed, people depended mostly on hunting and collecting edible plants from the wild for food.

However, Western lifestyle influences modified the dietary lifestyle of people, including the utilisation of calciferous vegetables rather than the utilisation of indigenous vegetables (Achigan-Dako et al., 2014). In rural communities, agriculture is appreciated as an important source of employment for rural people. The cultivation of vegetables plays a significant role in the reduction of poverty and food insecurity. Therefore, encouraging the cultivation and commercialisation of indigenous vegetables like *Amaranthus* has shown to provide quality nutrition and a better livelihood for many people in rural communities. Even though *Amaranthus* is one of the most important sources of nutrition in the diet of rural communities, information on the species consumed is scarce/limited. Therefore, species of *Amaranthus* have not been given much attention by researchers. Similarly, there is no or little research on production, processing, and marketing of *Amaranthus* vegetables, let alone its food products.

Some commercial farmers in the South Africa sell *Amaranthus* through formal markets by an agreement. However, small holder farmers, including *Amaranthus* sellers, need more support if they are to produce and sell their products through informal markets (Emmanuel and Babalola, 2022). There is hardly any research on challenges and opportunities that integrates *Amaranthus* into the conventional agricultural value chains. Hence, this study investigates the most commonly sold/consumed species with their challenges along the simple value chain. The findings may provide or generate information for future studies.

4.2 The concept of 'value chain'

A value chain is the process in which products go through different stages, starting from production and transformation of the produce. The stage starts with input from the suppliers to processors to exporters and consumers who are the buyers. The value chain encompasses those who are engaged in the activities that are required to bring an agricultural product from its production stage to its end use (consumption) stage (Senyolo et al., 2018). The value chain has interesting features because it involves a holistic activity that monitors all the processes and the constraints that may occur along the value chain. The value chain of *Amaranthus* includes the set of actors that relates to the functioning of a specific product, which in turn adds or increase its value throughout the different linkages of the value chain, beginning from the production stage to the consumption stage, including the commercialisation of the product. In the field of marketing and distribution a value chain is seen as the various activities that an organisation develops to take a product from the producer to the consumer within a business system.

4.3 Importance of the value chain

Value chains are necessary because they allow the most efficient use of resources, with distribution and marketing playing a key role in improving competitiveness in the market. A value chain improves the flow of information between actors, and helps develop solutions in a joint manner, especially by identifying problems and hold-ups throughout the chain. Lastly, a value chain allows independent and joint analysis of each link along the chain (Peña et al., 2008). Broadly, a value chain aims to provide the commercial connections and flows of inputs, products, information, financial resources, logistics, marketing, and other services between producers, suppliers of inputs, processing plants, exporters, retailers, and other economic agents who participate in the supply of products and services to the final consumers (Senyolo et al., 2018). A value chain is also considered an agreement or strategic network between several independent organisations within a productive chain (CIAT, 2007).

4.4 *Amaranthus* and its challenges along the value chain

There are many species of *Amaranthus* so they are often difficult to characterise taxonomically. This challenge is due to the overall similarity of many of the species, some are small and it is difficult to see the diagnostic parts, and they have broad geographical distribution, which is the reason for many of the synonyms (Kaplinsky and Morris, 2000; Senyolo *e*t al., 2018; Aderibigbe et al., 2022). *Amaranthus* is a multipurpose plant and is an excellent source of nutrition for both animals and humans. However, despite its usefulness in human nutrition, it is a plant that is side-lined and thus, underutilised along its value chain. Hence, *Amaranthus's* plant potentials have yet to be explored in many staple foods.

Research on agriculture and rural development policies and programmes are mostly focusing on other plants compared to the research done on indigenous vegetables like *Amaranthus*. There is less attention on 'who' takes responsibility for 'what' because of the lack of services of the agricultural extension and agricultural credit of smallholder farmers of *Amaranthus*, and there is a lack of storage facilities which is a constraint militating against the marketing of

Amaranthus along the chain. (Senyolo et al., 2018; Dizyee et al., 2020; Aderibigbe et al., 2022). This in turn forces traders to buy *Amaranthus* in small quantities that can only be sold in a day or just a few days. Also, *Amaranthus* is highly perishable. The lack of storage facilities is one of the main reasons for spoilage and product losses, particularly at the retailer point of the value chain (Senyolo et al., 2018). Furthermore, inadequate infrastructure including shades where the street vendors can display their produce on the market places are lacking hence subjecting the *Amaranthus* to increased dehydration in the leaves, causing wilting, to spoilage to losses; this often forces the sellers to reduce the prices and sales (Aderibigbe et al., 2022). Mismanagement of any perishable foods, including *Amaranthus,* has been identified as a serious challenge in the marketing and distributing aspects of the value chain (Chagomoka et al., 2014). This is because the perishability nature of vegetables, especially *Amaranthus,* often leads to a drastic loss of quality after harvest before it reaches the consumption stage. Lack of proper management of the perishability of any perishable food produce can pose challenges in the distribution and marketing aspects, which by extension may deprive the consumer of the holistic nutrients of the vegetables. In addition, finance is a constraint that small holder farmers and traders of this vegetables are challenged with because it prevents them from producing *Amaranthus* on a larger scale as well as buying the *Amaranthus* on a larger quantities for sale (Boateng et al., 2016). The incorrect perception that *Amaranthus* is a crop for common people may affect the patronage of *Amaranthus.* It is well known that *Amaranthus* leaves are the cheapest however, they are not being purchased in the same volume compared to other exotic vegetables like cabbage, lettuce, kale, broccoli and the likes (Boateng et al., 2016; Ndlovu, 2020). The same factors limit the supply; hence, lack of capital and spoilage are major problems confronting the management of *Amaranthus* along its value chains of small holder farmers (Chagomoka et al., 2014; Boateng et al., 2016). Challenges such as lack of skills also affect the farming and marketing of indigenous vegetables, including *Amaranthus,* in South Africa.

4.5 Challenges facing the farmers of *Amaranthus*

It is reported that *Amaranthus* smallholder farmers have difficulty in accessing agricultural support and services (credit and extension services) (Senyolo et al., 2018). This means that although smallholder farmers are highly motivated to become commercial farmers, they are minimally integrated into the value chain and thus, are excluded from accessing the mentoring and credit facilities that would aid their farming practices. Hence, their dream continues to be a mirage (Senyolo, Wale, and Ortmann, 2018). The main challenges along the value chain of *Amaranthus* include climate change and poor infrastructure, which hinders the possibility of benefiting from the value chain. The investigation of commonly sold *Amaranthus* along the value chains is crucial because very limited studies have investigated *Amaranthus* along the chain and related subjects (Chagomoka et al., 2014, Senyolo et al., 2018).

Past studies have investigated production systems, the characteristics, and the nature of *Amaranthus* and its marketing outlets, and the grains have been investigated (Senyolo et al., 2018). However, studies have hardly looked at the entire value chain of the most consumed/sold variety in the study area. Thus, this study aims at assessing the most sold variety while examining its challenges along the value chain in the study area.

4.6 Common species of *Amaranthus* in South Africa and their morphological characteristics

Amaranthus ssp. species are considered one of the commonly underutilised traditional vegetables in South Africa. Even though *Amaranthus* is hardly cultivated, some species have been grown in South Africa. These species include: *Amaranthus* (A.) thunbergii commonly known as Thunberg, A. *spinosus*, A. *hybridus,* A. *deflexus,* A. *hypochondriacus,* A. *greazicans,* A. *viridis,* A. *cruentus* and A. tricolour A. *dubius, A. caudatus* (Gerrano et al., 2015, Gerrano et al., 2015; Gerrano et al., 2017). The morphological characteristics of these species are discussed below.

Amaranthus Thunbergii is an erected variety of *Amaranthus* that can grow up to 50 cm. This species is found throughout Southern Africa, South Africa including KwaZulu-Natal (Van der Walt *et al.,* 2009; Achigan-Dako et al., 2014). Among these groups, it is grown mainly for the leaves purpose and consumed as any other leafy vegetables, that are used either as flavours or vegetables in the soups or served as side dish. The inflorescence of this species is greenish in axillary and is clustered with brown or shiny black seeds (Achigan-Dako et al., 2014).

Amaranthus spinosus also called spiny or pigweed amaranthus, the leaves are edible like any other leafy vegetables. *Amaranthus spinosus* is called spiny amaranth because its leaves have sharp spines of various sizes, usually found mostly in the wild, which can grow up to 100 centimetres (Ogwu, 2020; Jimoh et al., 2022). The stem of *Amaranthus spinosus* is angular, while the leaves alternate with the inflorescence made up of dense clusters; The seeds are black and shiny with a narrow margin and are mainly found throughout KwaZulu-Natal and Limpopo provinces in the South Africa (Achigan-Dako et al., 2014).

Amaranthus deflexus or perennial pigweed commonly known as large-fruit amaranth, it is an *Amaranthus* species that grows up to 50 cm having alternate leaves that do not separate into leaflets (Afrigis, 2022). Its inflorescence is usually dense, having a leafy characteristic at the base of the plant, with its seeds bigger than other *Amaranthus* species; the leaves are edible by animals and humans. They are mainly found in Limpopo and KwaZulu-Natal provinces in South Africa (Ogwu, 2020; Emmanuel and Babalola, 2022).

***Amaranthus hypochondriacu*s** is usually cultivated for its grain (Achigan-Dako et al., 2014). They have spirally arranged edible leaves that are used as any other leafy vegetable because it has a mild flavour. The plant is dynamic and erect, with its height ranging from 40–200 cm. Its stems are usually branched, mostly in the inflorescence. *Amaranthus hypochondriacu*s flowers are unisexual in nature and its seeds are either white, yellow, or black. This species mainly grows in the Northern Cape (Ogwu, 2020; Emmanuel and Babalola, 2022)

Amaranthus graecizans is the most wide-spread pigweed species that is mainly consumed as a leafy vegetable. (Ogwu, 2020). The leaves are arranged spirally, while the inflorescence is the axillary cluster. The height ranges from 50 to 150cm, and it strongly branches from the lower part (Aderibigbe et al., 2022). The flowers are yellow in colour, unisexual, and contain round black seeds. The species is known to be resistant to pests and diseases. *Amaranthus graecizans* is cultivated in KwaZulu-Natal, Mpumulanga and Limpopo (Gerrano et al., 2015; Ogwu, 2020; Aderibigbe et al., 2022)

Amaranthus Viridis This variety is commonly known as slender amaranth and is widely consumed as a leafy vegetable; it is an annual plant with an upright, light green stem. It can grow up to about 60–80 cm with branches that are angular, emerged from the base, while the leaves are oval (Ogwu, 2020). Its flowers are unisexual in nature, with seeds that are smooth and glossy, and they are commonly harvested from the wild though they are sometimes cultivated. The A. *viridis* mainly grows in KwaZulu-Natal and Limpopo provinces in the South Africa (Emmanuel and Babalola, 2022).

Amaranthus hybridus is generally known as smooth pigweed; it has green leaves with characteristics red blemishes but they are eaten as a vegetable (Jimoh et al., 2018). It can grow up to 180cm and can be harvested after 120 days of its cultivation. They are mainly found in Limpopo and KwaZulu-Natal provinces in South Africa (Emmanuel and Babalola,2022).

***Amaranthus Ccruentus*,** also known as purple or red amaranth, is one of the three amaranth species cultivated for their grain purposes in South Africa. The tender leaves are eaten as a leafy vegetable, while the seeds can be germinated and eaten as a nutritious sprout. The stems are branched, and leaves are arranged spirally, and it can grow up to 200 cm tall *Amaranthus cruentus* has unisexual flowers with tiny smooth seeds (Emmanuel and Babalola, 2022). *Amaranthus cruentus* is grown in KwaZulu-Natal.

Amaranthus tricolour belongs to the multi-coloured *Amaranthus* species that is usually consumed as leafy vegetables. They are usually seen growing in the wild and can grow up to 125cm. The leaves are arranged spirally with unisexual and smooth black or brown seed (Emmanuel and Babalola, 2022).

4.7 *Amaranthus* production in South Africa

The South African climate is considered favourable for the cultivation of *Amaranthus* (Emmanuel and Babalola, 2022). Irrespective of agroecology, *Amaranthus* is a summer plant that grows easily with little attention; however, in rural communities, it is commonly cultivated (Achigan-Dako et al., 2014; Aderibigbe et al., 2022). Unlike calciferous leafy vegetables, *Amaranthus* cannot withstand low temperatures; hence, the timing of *Amaranthus* cultivation has been an issue for researchers which needs to be addressed (Emmanuel and Babalola, 2022). Most of the varieties of Amaranthus prefer the warm temperatures ranging from 70 to 85 degrees Fahrenheitand the temperature should not be too low at night (Emmanuel and Babalola, 2022). This is because a low temperature can be injurious to the amaranth plant because it makes the plant to be fibrous and, in the end, bent.

Also, Amaranthus are photoperiod-sensitive, meaning that they are responsive to relative length of light and dark periods; they start flowering if the day length is less than 12 hours (Emmanuel and Babalola, 2022). However, it has been identified that a longer periods, like twelve hours of day length, can help to increase the number of phytochemicals and other antioxidants present in the leaves, which is of advantage to the consumers (Achigan-Dako et al., 2014; Emmanuel and Babalola, 2022). Water scarcity is identified as a major concern for crop production in South Africa, but amaranth is a C4 plant so is drought-tolerant which places it in an advantaged position for local production with little attention. Notwithstanding, a prolonged dry spell is likely to induce early flowering of the amaranth plant, which decreases leaf yield and thus will affect the market quality (Achigan-Dako et al., 2014; Emmanuel and Babalola, 2022). *Amaranthus* usually grow in the wild and are being cultivated by smallholder farmers that have small plots of marginal land with access to irrigation and other agronomic input (Emmanuel and Babalola, 2022). In other to facilitate yield, supplementary irrigation has been considered essential, especially after transplanting or even when sowing directly. There has been little commercial production of *Amaranthus*, hence there is a scarcity of data on its commercial level of production (Achigan-Dako et al., 2014; Aderibigbe et al., 2022). Notably, data for *Amaranthus* are also scarce, perhaps because the African leafy vegetables are combined, and *Amaranthus* cannot be easily separated (Maseko et al., 2017).

4.8 Challenges of amaranth production in South Africa

Amaranth, like other underutilised indigenous leafy vegetables is facing lots of challenges in South Africa. It is reported the amaranth value chain is not organised, with most of the vegetables harvested in the wild (Van der Merwe et al., 2016). Generally, the main challenge facing underutilised crops, including *Amaranthus* is the competition with other conventional crops, and most innovations are tilted toward the grain *Amaranthus* crops. There is less interest in the nutritional value of wild vegetables including amaranth. Hence, its production is still at a low level. Creating more awareness may help to emphasise its nutritional composition. Therefore, beyond knowing the nutritional value of amaranth, identifying the most consumed and determining its application in staple foods preparation as well as the conditions required for their production, educating farmers, enlightening the people, and, in turn, increasing its public acceptance, are lacking. Little availability of extension services and limited research on it from within the field of agroecology, are some of the reasons why *Amaranthus* is still underutilised in country and perhaps where they are being domesticated.

4.9 Materials and method

This study was community-based research; hence, a mixed method comprising qualitative and quantitative approaches was adopted and used to reveal information regarding the research question and objectives under study. The mixed design methodology was suitable because it assists in providing a strong foundation for community-based participatory research (Ivankova, 2017). Community-based participatory research is a research approach that is collaborative in nature, and seeks the community members' opinions. In this study, six key informants from each of five open markets were used. This study also included formal marketers of *Amaranthus* in formal markets, three upper class, three middle class and three lower class. Only the supervisors of the fruits and vegetable section of these selected formal markets were included as key informants. Also street vendors and farmers of *Amaranthus* in the rural community of the Empangeni (peri-urban) based market and the Bangladesh market as in Chatsworth, Durban (urban), were included as key informants in this investigation. The approach of qualitative research helps to gather participants' experiences, perceptions, and behaviours. It seeks to answer all the "how's and whys" instead of just "how many or how much". The qualitative research design involves the use of semi-structured interviews questions (Tenny et al., 2017). Quantitative research design is used to produce data that is based on quantifiable/discrete values. Hence, each design was used in this study while qualitative was used to capture people's opinions, a quantitative research design was utilised to collect the respondent's demographic data, which deals with discrete values (Asenahabi, 2019).

4.10 Sampling technique

Purposive convenience sampling was used to gather data from both *Amaranthus* sellers and farmers. Inclusion criteria were that participants had to be from a formal marketers of *Amaranthus* (three from upper class, three from middle class, and three from the lower-class markets), or informal marketers (street vendors of *Amaranthus*). These categories of people were purposively selected as they constitute the producers, and input sources. Purposive sampling is a non-random sampling method, it includes those that have expert knowledge are available and are willing to participate in the study. Selection in this form of non-probability sampling is based on the characteristics of the population and the objectives of the study. Four to six key-informant interviews are recommended in the literature (Muellmann et al., 2021). The assessment of this study relies on semi-structured interviews with key informants in the communities. This strategy was used to explore the aims and objectives of the study, and to provide enough variety so that various points of view and ideas and issues are represented in the sample (Robinson, 2014; Campbell et al., 2020). Three key informants that are supervisors of fruit and vegetable section were selected. Three from each economical status upper-class, middle class ,and low-class respectively from the formal markets in rural and urban area were interviewed. Similarly, *Amaranthus* sellers in the informal markets in the urban centre at formal market A, B and C was also targeted and included in the study. The data were collected bearing in mind the most common variety of *Amaranthus* sold by the vendors and in the malls and assessing the *Amaranthus* along it value chain.

4.11 Description of the study area

The study was conducted in the province of KwaZulu-Natal, in Empangeni, which is a town 160 km away from Durban along the R34 off the N2; the town is positioned in the hilly countryside of the uThungulu district. The surrounding environs of Empangeni is known as a centre for cotton, cattle, timber and sugarcane plantations. It is only 15 km away from Richards

Bay on the coast, and these two towns, together with Vulindlela, Esikhawini, Felixton, Nseleni, and Ngwelezane, make up the city of uMhlathuze. Empangeni was originally the location of a Norwegian Mission station founded near the stream called Empangeni, which was later moved to Eshowe. The name Empangeni, according to folklore, comes from a Zulu word known as 'pangaed', which means 'grabbed', referring to the number of crocodile attacks on water bearers in the nearby Empangeni stream. The geolocation of Empangeni is -28°44'50.3868",31°54'42.7078" (SAHO, 2017). Information regarding commonly sold *Amaranthus* in formal and informal markets in the urban locations of Durban KwaZulu-Natal province informal market A, B and C and Empangeni, the market called Town, or station-market) and Esikhawini market were included in the study.

4.12 Data analysis

The data in this study was analysed using descriptive narrative content analysis.

4.13 Ethical issues/permission

Ethical permission for the study was obtained from the University of KwaZulu-Natal Research Ethics Committee, reference number **HSSREC/00000435/2019**. Participants' willingness to partake in the study was obtained using informed consent forms that were provided by the researcher and signed by each participant before the commencement of each interview. The consent forms specified that participation in the study was solely voluntary and that participants were free to decline to participate or withdraw from the study at any time they chose to.

4.14 Value chain analysis of *Amaranthus*

The value chain of *Amaranthus* in the study area is undeveloped, meaning that there is no infrastructure. The main actors in the value chain are input suppliers, smallholder farmers, traders (such as retailers, street vendors/hawkers), and consumers. The first marketing channel starts from the smallholder farmers to the trader (street vendors/hawkers) or consumers. Some smallholder farmers sell directly to the middlemen (collectors/distributors) who take their *Amaranthus* to retailers. The end market of *Amaranthus* is household consumption.

4.15 Results and discussion

Tables 4.1 and 4.2 describe the demographics of informal marketers of *Amaranthus* in the rural community (Empangeni) and urban community (Durban). The age group of participants ranged between 26 and 60 years, with then majority of them being within the age bracket of 41 to 60).

The leading sellers of *Amaranthus* in the eMpangeni station market and Esikhawini local market were 100% (n = 6) black African women as described in Table 4.1.

Table 4-1: Sociodemographic characteristics of *Amaranthus* vendors in Kwazulu-Natal province (Rural)

Sociodemographic characteristic	Market X Frequency (%)	Market Y Frequency (%)
Age Group (years)		
26-30	0(0)	0(0)
31-40	1(16.7)	1(16.7)
41-50	2(33.3)	4(66.6)
51-60	3(50.0)	1(16.7)
Race		
Black Africans	6(100.0)	6(100.0)
Indians	0(0)	0(0)
White	0	0
Gender		
Males	0(0)	0(0)
Females	6(100)	6(100)
Educational status		
Informal	1(16.7)	3(50)
Primary	3(50)	2(33.3)
Secondary	2(33.3)	1(16.7)
Tertiary	0(0)	0(0)

Similarly, in Table 4.2 Black African women were the majority in the urban informal market settings. However, Indian men, women, and black African women bought and sold *Amaranthus* in the Chatsworth open market (popularly known as the Bangladesh market). The study shows that n = 6 (100%) of the population of this study were black African females. This study agrees with the study reported by Senyolo. (2018), who reported that most farmers and marketers of south African vegetables, including *Amaranthus* are females (Senyolo et al., 2018).

Table 4-2: Sociodemographic of informal marketers of *Amaranthus* in (urban)

Sociodemographic characteristic	informal market A Frequency (%)	informal market B Frequency (%)	informal market C Frequency (%)
Age Group (years)			
26-30	0	0	0
31-40	1(16.7)	1(16.7)	1(16.7)
41-50	2(33.3)	2(33.3)	3(50)
51-60	3(50)	3(50)	2(33.7)
Race			
Black Africans	2(33.3)	6(100)	6(100)
Indians	4(66.7)	0(0)	0(0)
Gender			
Males	4(66.7)	0(0)	0(0)
Females	2(33.3)	6(100)	6(100)
Educational status			
Informal	1(16.7)	1(16.7)	2(33.3)
Primary	3(50)	3(50)	3(50)
Secondary	2(33.3)	2(33.3)	1(16.7)
Tertiary	0(0)	0(0)	0(0)

Although it is often perceived that street vendors were the least educated, in this study a significant percentage of the participants were literate, as n = 3 (50%) of them in both locations had primary school education. However, in comparison, n = 2 (33.3%) had secondary school education, and very few, n = 1 (16.7%), had informal education, respectively. The Chatsworth market is situated in an Indian community; it is an open market that operates twice a week (Fridays and Saturdays) and is patronised by Indian men and women and black African men and women. However, a significant percentage, n = 4 (66.7%), of the people selling *Amaranthus* in informal market A. On the other hand, n = 2 (33.3%) of the Africans selling *Amaranthus* were women. *Amaranthus* is considered as a food plant that provides nutrition and a means of livelihood for the sellers of *Amaranthus;* hence, during the study it was observed that most of the sellers of *Amaranthus* were self-employed because they were mainly traders of indigenous vegetables including *Amaranthus.*

Table 4.3: Formal marketers of *Amaranthus* in (Empangeni)

Formal markets	**Commonly sold variety of *Amaranthus***	**Source of the *Amaranthus;* farm/supply**	**Remarks**
Upper class1	Not applicable	Not applicable	Out of range of goods sold
Upper class 2	Not applicable	Not applicable	Slow selling vegetable hence out of range of vegetables sold
Upper class 3	*Amaranthus spinosus* and red and green A. *Cruentus*	Supply	Fast selling vegetable
Middle class	*Amaranthus Curentus* and *spinosus*	Supply	Fast selling vegetable
Middle class	*Amaranthus spinosus* and red and green A. *Cruentus*	Supply	Fast selling vegetable
Middle class	Not applicable	Not applicable	Out of range of selling goods
Lower class	Not applicable	Not applicable	Out of range of selling goods
Lower class	Not applicable	Not applicable	Out of range of selling goods
Lower class	Not applicable	Not applicable	Out of range of selling goods. (This implies that it is not goods that are sold in their market)

Table 4.3 shows that only one of the upper-class malls sells Amaranthus in the urban malls. The others attest that *Amaranthus* is out of the range of their selling goods. Similarly, in Table 4.3. two of the middle class markets that sell Amaranthus do not own a farm of their own but are being supplied farmers. The lower class formal markets are not selling *Amaranthus* because *Amaranthus* is sold on the street close to the formal markets.

Table 4-4: Formal marketers of *Amaranthus* in (Durban)

Formal market	Commonly sold varieties of *Amaranthus*	Source of the *Amaranthus;* Farm/supply	Remarks
Upper class 1	Not applicable	Not applicable	Out of range of goods sold
Upper class 2	Not applicable	Not applicable	Slow selling goods Hence, out of range of vegetables sold
Upper class 3	*Amaranthus spinosus* and red and green A. *Cruentus*	Supply	Fast selling vegetables
Middle class 1	*Amaranthus Curentus* and *spinosus*	Supply	Fast selling vegetable
Middle class 2	*Amaranthus spinosus* and ed and green A. *Cruentus*	Supply	Fast selling vegetables
Middle class 3	Not applicable	Not applicable	Out of range of selling goods
Lower class 1	Not applicable	Not applicable	Out of range of selling goods
Lower class	Not applicable	Not applicable	Out of range of selling goods
Lower class	Not applicable	Not applicable	Out of range of selling goods sold

Table 4-4 shows that only upper-class numbers 3 sells *Amaranthus* vegetables, with the other two upper class markets attesting that *Amaranthus* is out of the range of their selling goods. Upper class 2 stated that when they stocked *Amaranthus* it was slow selling therefore was dropped from the range of vegetables sold. Similarly, Table 4-3 shows that the two of the middle class markets that sell *Amaranthus* do not own farm land of their own, hence, *Amaranthus* vegetables are being supplied to them. The lower class markets are not selling *Amaranthus* because it is sold on the streets close to where the malls are located.

4.16 Informants' general knowledge common species of *Amaranthus* in eMpangeni

KwaZulu-Natal, especially Empangeni, is endowed with a variety of indigenous vegetables. All the key informants interviewed in the study area were familiar with most of these vegetables. The indigenous vegetables being sold in the study site also included *Imbuya*, *Imfino Yamathanga* (Pumpkin leaves), and *Intshungu* (bitter leaf) spinach *ugobolo*, which were sold in the urban market. *Amaranthus* was the most familiar and cheapest indigenous vegetable in the study site. Although 65 to70 Amaranths have been domesticated worldwide, *Amaranthus spinous*, a wild species also known as pigweed, *Amaranthus dubius,* and the red and green A. *cruentus* were the most common and popular species grown in the Empangeni.

The *Amaranthus spinous* was observed growing along the roadsides, fallow lands, and refuse dump sites, i.e., being grown without cultivation. The current study agrees with previous studies that report that *Amaranthus spinous* is generally harvested in the wild (Achigan-Dako et al., 2014). Empirically, *Amaranthus* is more cultivated in rural areas compared to urban areas. In this study it was identified as growing in-between other crops without being cultivated. *Amaranthus* was known to be a good and healthy plant with health benefits in the study area. However, the key informants have no scientific/nutritional knowledge of the nutritional composition of *Amaranthus.* Most of the informants attested that they grew up eating *Amaranthus* as an indigenous food. An informant in Durban said "*Amaranthus* contains vitamins; hence, when people are sick, they usually eat *Amaranthus* because it is considered an excellent plant for human consumption since it is a crop that is naturally grown and is free from chemicals and industrial fertilizers".

4.17 Cultivation of *Amaranthus* before harvesting

The planting season for *Amaranthus* is usually in late spring or early summer, germinating 3 to 7 days after planting. Most of the wild *Amaranthus* variety grow in-between other crops after the establishment of the rainy season without needing to be planted. The plant grows for two weeks before the physical appearance of the leaves. An informant reported that within two months of planting, broad leaves, and flowers of the amaranth plant manifest. Even-though *Amaranthus* is a drought-resistant plant, *Amaranthus* only starts germinating after the rain had been established or when an irrigation plant is used to water the plants. Germination and growth are evident when there is a shoot from the seeds, leaves flourish, and the length and size of the plant increases by the day. The *Amaranthus* is ready and harvested within two months of germination. The quantity yield and quality of the *Amaranthus* leaves is a crucial determinant of the harvesting time; the harvesting is done only when *Amaranthus* leaves are still green, tender, and fresh; the freshness of *Amaranthus* is ascertained when the stems are tender. Prolonged time leads to over maturing of Amaranthus; and the overmatured *Amaranthus* stems becomes tough and challenging, and people do not buy such, because it is considered stale and of low quality. Hence, *Amaranthus* should not be allowed to be old before harvesting as the buyers usually do not patronise the tough stems ones.

4.18 *Amaranthus* cultivation among the informal marketeChatsworth*nthus*

Informants from Informal market A within the Durban metropolis, stated that *Amaranthus* grows without it being planted in, which the statement is consistent with the findings of

Gerrano et al. (2013) and Achigan-Dako et al. (2014). Some informants have sizable farmland and gardens where a portion is used for the cultivation of *Amaranthus* but, those who do not have farmland buy *Amaranthus* from the market. However, one of the informants has a big garden; he estimated the land by saying was about the size of a soccer field. In contrast, those with household gardens for *Amaranthus* usually utilise the backyard area of their house or beside their homes. One of the Indian *Amaranthus* sellers owns farmland of 5 to 7 hectares, where he cultivates other crops alongside *Amaranthus.* In the nformal market A, an Indian informants stated that he grow his *Amaranthus* at the back-/frontyard of the house.

4.19 Type of labour utilised by the smallholder farmers

Most small-scale farmers and sellers of *Amaranthus* cultivates it themselves because skilled labour was said to be expensive. The study reveals that most informants utilise unskilled labour to grow their *Amaranthus*; however, sometimes family members and other relatives assist in the cultivation of *Amaranthus.* Thus, there was no skilled or mechanised farming involved in small-scale farming of the Amaranthus. However, historically, donkeys have been used for the cultivation of *Amaranthus,* which is no longer in practice today.

4.20 Economic importance of growing *Amaranthus* in a rural and urban centres

Although there are several species of *Amaranthus* grown across the world and in Africa, the leafy species comprising A. *spinosus* which include the *dubius* variety and the red and green A. *cruentus* were the most grown *Amaranthus* in Empangeni KwaZulu-Natal. These species are mainly grown for household consumption. However, it was found in the study that *Amaranthus* is not consumed by the farmer alone but is sometimes given out to relatives and other people as an act of kindness. Besides consumption, *Amaranthus* is also grown and sold to solve different household needs; this means that *Amaranthus* serves as a source of employment for the informants and other community members. However, the lands used to cultivate *Amaranthus* are usually not large, thus informants cultivate the land themselves. In the informal market A open market one informant said that he had been growing and supplying *Amaranthus* vegetables for a period of 22 years. All kinds of people including adults who are black South Africans, black foreigners, coloured, and Indians, patronise the *Amaranthus* leafy vegetables. However, the blacks and Indians are the most frequent buyers of *Amaranthus.* Those with gardens and farmlands sell a lot during summer season, while those who get from suppliers sell only when it is available.

4.21 Commercialisation of *Amaranthus* (bundle size, weight, and cost at formal markets)

In the urban formal market, it was revealed that their *Amaranthus* are obtained from South Dune in La Mercy in Durban. The farmer supplies *Amaranthus* to the formal in bunches which weighs 232g and is usually sold at R5 before the Covid and the flood that caused lots of destruction in KZN. However, after the Covid 19 and the flood, the price of the same bunch increased to R7.99, sometimes rising to R10 per bundle of amaranth depending on how much their suppliers sells to them. Despite the rise in the price of food, *Amaranthus* is still the cheapest indigenous leafy vegetable.

4.22 Frequency of sales of *Amaranthus*

All the key informants sell *Amaranthus* daily, except for one person who sells *Amaranthus* only when the supplies are available. Cultivation and consumption of *Amaranthus* are mostly at their peak in summer because that is when *Amaranthus* is being harvested even in the wild.

4.23 Farmer's current perception of *Amaranthus*

The informants attest that, even though *Amaranthus* is linked with less-privileged persons, it is a home-grown vegetable that is well known, and it is appreciated by the community members. It is a valuable plant because it is perceived to be the most natural plant that grows organically almost everywhere; a such, it is free from chemical fertilisers. Moreover, it is a food plant that their ancestors appreciated; hence, it was said that it is a plant that has been passed down to their generation which must be retained. They are not precise about the nutritional values in *Amaranthus;* however, they consider it "as a plant with various medicinal and healing effects which can sustain one's health". This investigation can be likened to those studies reported by Achigan-Dako et al. (2014) and Aderibigbe et al. (2022). Although, it is established that *Amaranthus* is a nutrient-dense plant with several medicinal healing potentials (Aderibigbe et al., 2022), it is neglected plant partly because of its association with marginalised people in society.

4.24 Smallholder farmers of *Amaranthus*

In the study area, *Amaranthus* are mainly produced and sold by smallholder farmers. Most of them practice their farming system on less than one hectare of land around the home environment, and cultivate *Amaranthus* alongside other indigenous vegetables. Smallholder farmers follow the traditional practices for *Amaranthus* production, using localised farming systems. Some smallholder farmers are involved in saving and supplying input services such as seeds that they have harvested from the previous farming of *Amaranthus.* Given that there is a relatively high perishability level of leafy vegetables including Amaranthus, the producers are sometimes compelled to sell their produce immediately after harvest, which leads to low farm gate prices.

4.25 Intermediaries/traders

Traders buy products (*Amaranthus*) from producers to resell them to retailers or consumers (Aderibigbe et al., 2022). In this study, women were the main producers of *Amaranthus* as well as the middlemen whose main functions included the collection of *Amaranthus* from the producers. They maintained the quality of the products by covering them in sacks to preserve their freshness until they were transferred to the next following agents, who were the street vendors of *Amaranthus.* The actors in the value chain of *Amaranthus* in the rural community mainly sell *Amaranthus* for household consumption and to generate money for other utilities in the house. However, the large retail (supermarket) stores such as middle class 1 and middle clsass 2 and upper class 3, reported that that they have contract agreements with their approved suppliers and distributors who meet the quality and standards of the *Amaranthus* vegetables, which is done through their distributors (Aderibigbe et al., 2022). Fresh Mark is one of the major distributors who buys vegetables from smallholder farmers. Some formal markets such as upper class 3 and middle class 2 have a direct relationship with small scale farmer because they small-scale traditional African leafy vegetables which can be obtained directly. All these supermarkets trade with smallholder farmers without any formal contract. Once the quality of the product is acceptable, they buy on the spot. The open market is similarly operating successfully in Empangeni station market and Esikhawini local market; the sellers buy *Amaranthus* directly from farmers/suppliers, hence there is no formal contract between the open market and the farmers.

4.26 Processing of *Amaranthus*

Amaranthus dubius leaf extract has been investigated (Harshiny et al., 2015). Some leafy vegetables like *Moringa oleifera* have been processed into leaf powder. However, the processing of *Amaranthus dubius* into powder has scarcely been documented. Smallholder farmers' old method of sun drying vegetables was practiced in time past, but is rarely practiced in this era. Currently, modern forms of food processing and preservation methods include the use of canning and branded packaging. These food processing methods aim to meet the needs and preferences of the young generation and urban dwellers, which are not practiced along the

Amaranthus value chain. Hence, the younger generation and urban dwellers rarely consume *Amaranthus* that are processed locally. Along the value chain, *Amaranthus* is sold locally in its fresh form in both formal and informal markets. *Amaranthus* is marketed through three channels: smallholder farmers selling directly to consumers, smallholder farmers selling to retailers, and smallholder farmers selling directly to middlemen (collectors).

4.27 Value chain of *Amaranthus*

Figure 4-1 illustrates the simple value chain where various actors have a link in the chain that facilitates *Amaranthus* production and services from the producers to the plates. Farmers cultivate *Amaranthus* and supply it to intermediaries who sell it to retailers and consumers.

4.28 Strength along the *Amaranthus* value chain and the economic benefits

It is interesting to note that *Amaranthus* was a source of employment as most of the participant traders of indigenous vegetables and *Amaranthus* were self-employed. It was identified that "*Amaranthus* is a quick-growing and selling vegetable".

4.29 Marketing channels for *Amaranthus* vegetables in Empangeni

Figure 4-1 describes the value chain of *Amaranthus* in the study area. Generally, *Amaranthus* is mainly sold via the three channels: (1) smallholder farmers selling directly to consumers; (2) smallholder farmers selling to retailers; and (3) smallholder farmers selling directly to middlemen (collectors).

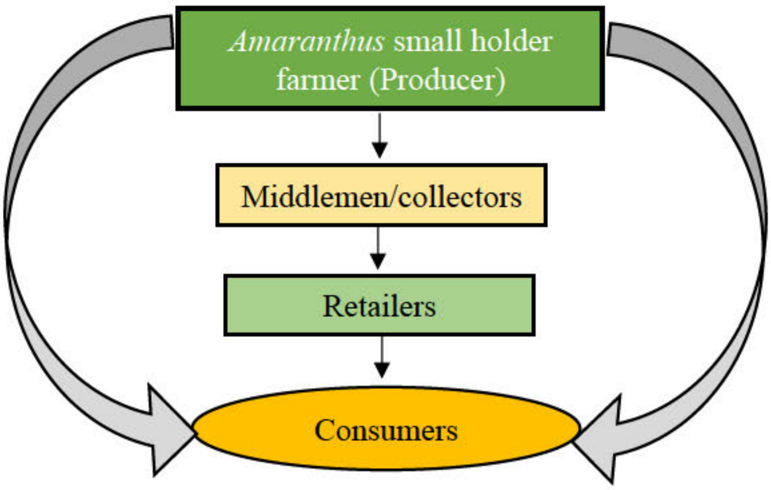

Figure 4-1: Simple value chain of *Amaranthus*

4.30 Common ingredients used in *Amaranthus* food-based products

In the study site, it was noted that *Amaranthus* leafy vegetables (*imbuya*) are prepared by using common ingredients, namely, oil, onions, and salt. Optional ingredients are chilies, tomatoes and seasoning with a *knorox* stock cube.

4.31 Proximity and transportation of *Amaranthus* to the market

Amaranthus is harvested and immediately transported by taxi to the market. However, one of the key informants waits for 2 days before supplying the Amaranthus because he uses an overnight means of transportation as the only option. Three key informants that have small garden plots sell their *Amaranthus* from their houses, while some sell them in front of their homes. Those with bigger farmland take theirs to the open market, which is about a 2 to 3 hour drive from the farmland. Most of the *Amaranthus* sellers do not have a car. Hence, taxis are the most common source of transport for transferring *Amaranthus* from farmland and garden to the point of sale. Very few informants use a bakkie for supply. Some of the *Amaranthus* sellers do not supply to other sellers, but those who do, supply to markets, to markets including informal markets A. Most times, *Amaranthus* is provided to buyers in the morning hours. It is supplied immediately after harvesting within the maximum period of two days. Sometimes, when it is harvested in the evening, it is transported overnight. This is done to minimise post-harvest losses.

4.32 Indigenous knowledge system surrounding *Amaranthus*

Indigenous knowledge systems (IKS) include the beliefs and knowledge developed within indigenous societies, which is not dependent on the advent of the modern scientific knowledge system (Tharakan, 2017). During the study, it was noted that there are cultural and ritual beliefs linked with *Amaranthus.* This study revealed that *Amaranthus* is used for prayers to God and in relation to ancestor ceremonies and sacrifices for the dead. This finding is consistent with studies in America where it was reported that *Amaranthus* was used for religious purposes in ancient times of the Mesoamerica. During that era *Amaranthus* was significant in the worship of gods as the seeds were used to make foods that were served during religious ceremonies. In this study, the informants said that *Amaranthus* is one of the indigenous vegetables that are used for praying to the ancestors because the ancestors will have eaten *Amaranthus* during their lifetime, and is a natural food that the ancestors will have appreciated during their lifetime. It is often cooked with *Ama bata* (sweet potatoes) and presented to the ancestors when praying.

Cooking *Amaranthus, cocoyam, mbili* in the shrine in the presence of candles. Some cultures use *Amaranthus* to prepare food that will be served during ceremonies like the Heritage Days ceremony as indigenous food. Some traditional ceremonies involve cooking *Amaranthus* with *Isiqwamba,* which is made from maize, which is then placed in a shrine.

4.33 Complimentary food for *Amaranthus*

Amaranthus are usually served with complimentary food like *isigwamba, Ama batata* (sweet potatos), and *Uphutu.*

4.34 Post-harvest practices

4.34.1 Cleaning practices of *Amaranthus* vegetables

Cleaning of the *Amaranthus* includes trimming, which is done by cutting off the *Amaranthus* roots and stems. This is done to get rid of garden/farm soil or compost debris that comes along with the plant; hence, trimming practice are being done for cleanliness before it is sold. The roots are trimmed down because they are not edible. Stems are often trimmed down before selling them. If the stems are tough, this implies that the *Amaranthus* was harvested more than two days previously so are not fresh. However, trimming of the fresh stems results in a quality and quantity loss because the tender stems of the *Amaranthus* vegetables are loaded with nutrients hence discarding it amounts to a loss of quality. In the station market in Empangeni, *Amaranthus* are not weighed; the vendors usually quantify Amaranthus leafy vegetables by estimating it using three hands full packaged in white plastic bags for sale at R10 per plastic bag. Similarly, the vendors in the urban setting are display on *Amaranthus* a table, using a perforated plastic bottle to sprinkle water over the leaves to conserve their freshness.

Post-harvest loss can be a significant source of waste of produce in an agricultural value chain; efficient post-harvest management that reduces post-harvest losses is therefore, vital for sustaining the entire value chain of any crop. Is it can be a key-factor in achieving food and nutrition security even in sub-Saharan Africa (Ambuko et al., 2017; Apolot et al., 2020). Post-harvest loss for sub-Saharan African leafy vegetables is reported to be more than 50%, resulting from various constraints from "the field to consumer" in the value chain (Kirigia et al., 2017). The post-harvest management of leafy *Amaranthus* in the study area encompasses harvesting, cleaning, and packaging into sacks and plastics that are tied into bundles before they are sold to the middlemen or before transporting them to the market. Although few operations are being practiced in the aspect of the value chain, however, they are practiced in detailed with keen attention, which is done to minimise the losses of *Amaranthus* along the chain. Diverse post-harvest practices have been carried out and reported in different ways.

Post-harvest losses are summarised into different categories namely: physical, otherwise known as quantity loss, economic loss, and quality loss which is the nutritional loss (Gogo et al., 2017). Physical quantity loss in loss of plant material meant for consumption. Quality losses usually happen when food is polluted, for example, with contaminants like microbiological or chemical substances that can downgrade a food product and reduce its market value. Failure to sell quickly can deteriorate a plant's texture, colour, or flavour. Physical and quality losses are the most common condition that leads to economic losses. Economic loss happens when parts of the products are lost or when the monetary value decreases because of the types of loss (Affognon et al., 2015). Quality loss can happen during food preparation processes and food handling practices which in the long run leads to the loss of the nutrient content of the food, which exemplifies the loss of micronutrients in various food which may leads to hidden hunger (Sheahan & Barrett, 2017). Thus, to reduce hunger, it is crucial to find suitable interventions for a sustainable post-harvest losses if we must reduce all the types of post-harvest losses. This is because studies have shown that post-harvest loss can happen during any stages of the value chain but can be severe at certain stages, depending on the crop. During harvest, several factors play a role in food loss: wrong harvesting times can lead to over-maturity of crops, which can result in food spoilage or loss of quality of the produce. Weather patterns can subject one to delay or rush in harvesting activities, leading to a significant loss.

4.35 The processing/preservation of the commonly sold *Amaranthus* among the informal marketers

There were no processing or preservation techniques of *Amaranthus* practiced at the study site. Rather the unsold *Amaranthus* was being discarded because it was no longer fresh. However, some sellers combine it with spinach to make soup for their families.

4.36 Marketers leftover *Amaranthus* vegetables

There is always a demand for *Amaranthus*, however, when the supply is more than the demand, the excess is wasted. Some informants indicated that in such cases they go door to door to sell it at a give-away price which helps them avoid wasting the leftover *Amaranthus* leaves. One informant stated that in the olden days excess *Amaranthus* was sun-dried and saved for the future use, but present-day people no longer or rarely do these practices. This implies that there are post-harvest losses of both quantity and quality losses along the value chain of *Amaranthus*.

4.37 Purchasers of *Amaranthus* leafy vegetables

All categories (races) of people: Indians, blacks, and white, who are adults within the low and middle class, consume the *Amaranthus* leafy vegetables. However, black Africans and Indians are the most common consumers of the *Amaranthus* leafy vegetables.

4.38 Challenges encountered by small-scale farmers while farming/selling *Amaranthus*

The common challenges small-scale farmers of *Amaranthus* experience while farming include lack of human resources, with mechanised farming that could enhance crop yield is absent. Other challenges are droughts, a shortage of rain and no water, the problem of the scarcity of seeds, poor soil texture and lack of fertilisers, lack of fences around their farmlands, and lack of chemicals.

One of the problems encountered during the study is that the vendors sometimes lacked buyers, which results in a reduction of price and loss of profits, and sometimes wastage. Storms and too much heavy rain affects the *Amaranthus* plants. A lack of land, financial support, the issue of climate change, and stigmatisation are commonly linked with people selling *Amaranthus;* they are being treated as insignificant and less privileged humans who are considered as not or less educated individuals. Also, high temperature and prolonged scarcity of rain during summer were identified as challenges that affect the yield of *Amaranthus* leaves, as reported by Senyolo et al., (2018). Although it is established that *Amaranthus* is a C4 plant (Achigan-Dako et al., 2014) this study found that a lack of or too little rain versus too much heat was a challenge that can lead to a reduction in the expected yield and harvest of many crops, including *Amaranthus.* Thus, the resultant effect of the lack/little rain scenario results in a low supply of *Amaranthus* vegetables. This is because only those that have access to irrigation-plant can thrive in such conditions. Hence, these small-scale farmers need education on how to handle the challenges of high heat. On the other hand, it was revealed that lack of rain during winter affects the cultivation. This is because *Amaranthus* does not germinate/do well in the winter season; and it is because the winter weather is too chilly for the plant to thrive; hence, this leads to a lack or limited supply of the *Amaranthus* vegetable yield during winter. By implication, the lackof or limited supply of *Amaranthus* during winter may reduce or block the source of income of small-scale farmers, thereby affecting their livelihoods. This implies that *Amaranthus* is a source of income in this community and when challenges are encountered their livelihood is threatened. However, another challenge is that the wild *Amaranthus (*pigweed) which are picked in the wild are overcrowded, and have to share the soil nutrient with the weeds in the field in which it is growing. Overcrowding either with weeds or other crops may tend to affect the yield and plentifulness of the harvest of the crop. Interestingly, despite all these challenges mentioned, some attest that there are no challenges except when there is no supply of *Amaranthus,* then income is lost; otherwise, they do not encounter any challenges along the value chain. Thus, the major strength identified during this study along the *Amaranthus* value chain is that both small-scale farming and the marketing of the *Amaranthus* contribute to the source of income of smallholder farmers since it was mentioned that *Amaranthus* provides money for other utilities besides food for sustenance; however, *Amaranthus* is a perishable food products so when there are no buyers postharvest losses and loss of resources occur.

4.39 Way forward

Considering the various constraints encountered along the value chain of *Amaranthus,* the following interventions are suggested: seminars and community engagement to promote and disseminate information on the *Amaranthus* potential and production techniques is highly needed. The small-scale farmers of *Amaranthus* should be trained in business and contract negotiation management which may encourage better financial returns. Small holder farmers should be encouraged to cultivate indigenous vegetables like *Amaranthus* (Aderibigbe et al., 2022). Thus fertilisers, seeds, and agricultural chemicals, should be considered as quality inputs. This is because attention is mostly on compost manure, locally available seeds, and local technologies that ensure the availability of inputs that encourage safe and healthy food for household consumption.

The absence of post-harvest technologies for processing and packaging *Amaranthus* is identified as a constraint in the value chain, suggesting that the training and skills in processing and packaging of *Amaranthus* by the public and private sectors might be a desirable alternative. Even though there is an increase in the growth of *Amaranthus* in the rural community, there is a loss in quantity and quality along the value chain; thus, food insecurity continues, and malnutrition continues to thrive (Chagomoka et al., 2014). These findings are consistent with the studies around postharvest losses of indigenous vegetables, where the supply of *Amaranthus* fails to meet the demand along the chain. Smallholder farmers face difficulties accessing high-value markets, such as supermarkets, and the middlemen regularly exploit them. They cannot supply the fixed quantity and quality consistently; these present opportunities for agribusinesses to add value and upgrade the existing value chains of *Amaranthus.* In addition, retailers are faced with the inability of smallholder farmers to supply the required quantity of *Amaranthus* on time. The challenge is that many smallholder farmers own a small portion of land, which means less supply, resulting in low and inadequate supply to the market. If smallholder farmers form and manage collective action organisations to supply *Amaranthus* (such as cooperatives), the problem of insufficient and poor-quality supply might be addressed. Marketing channels for indigenous *Amaranthus* involve simple family networks. The producer harvests and packages the product and ties them into bundles and bales.

4.40 Conclusion

Amaranthus is an underutilised crop and is endowed with micronutrient contents such as essential minerals and vitamins, phytochemicals, and bioactive compounds. *Amaranthus* can optimise well-being through its medicinal properties and through providing nutrition for animals and humans. *Amaranthus* can tackle malnutrition of all kinds with its qualities. It is a high-yielding and drought-tolerant crop, even in stressful weather conditions. *Amaranthus* is an indigenous crop with huge potential to provide food security and to redeem Africa from poverty and food and nutrition insecurity. The commonly sold species in formal and informal markets in eMpangeni were *Amaranthus cruentus,* A. *spinosus*, A. *viridis*. The green A. *dubius;* and A. *thunbegii* were seen in the Chatsworth market where the Indians called it sugarcane herbs. This important crop's potentials are yet to be explored, especially as a staple food. Therefore, there is a need for concentrated and continuous efforts in research that can coordinate all stakeholders of *Amaranthus* production. Also, the need for effective implementation of some relevant activities that can help in the domestication of *Amaranthus* cannot be overemphasised. Improving the small-scale farming of *Amaranthus* to large-scale appears to be the way forward. Government should assist small-scale farmers of *Amaranthus* which may may enhance their productivity. Policy makers should consider the provision of land, finance, fertiliser, seed, herbicides, insecticide, and grants to encourage farmers to plant vegetable foods like *Amaranthus.* Enhancing small-scale farmer's capital involves financial support from the government and the provision of land.

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CHAPTER 5: UTILIZATION OF UJEQE (STEAMED BREAD) AND AMARANTHUS LEAVES FOR IMPROVED FOOD AND NUTRITION SECURITY OF RURAL COMMUNITIES IN SOUTH AFRICA

Research Chapter: Accepted for publication (AJFAND)

Abstract

Food security remains the bedrock of the sustainable well-being of all nations. However, the dietary lifestyles of many persons are compromised by limited access to nutritious food, and this contributes negatively to the prevalence of malnutrition in developing countries. Bread, a wheat-based staple food, is consumed globally. However, mono consumption is linked with deficiency challenges, positioning it as an important medium for essential-nutrient delivery, especially among malnourished populaces. Bread supplementation is paramount for improved nutrient intake and well-being of its general consumers. Food-based strategies of diversified diet and nutrient intake via supplementation have been highlighted as a cost-effective and sustainable approach to tackling malnutrition. Therefore, the present study assessed the utilization of nutrient dense *Amaranthus* as a potential supplement in *Ujeqe* bread, a staple food consumed in Empangeni, South Africa. Mixed-design and purposive convenience random sampling were used in this study with 100 participants answered structured interview questionnaires on information regarding the utilization of *Ujeqe* and *Amaranthus*. Clustered data of 91 respondents were pre-processed, and analysed, using descriptive content analysis. Findings revealed that 92.59% of the respondents attested that *Ujeqe* bread is indigenous to the study area, and it is preferred because the ingredients are readily available, and preparation is easy. Moreover, *Ujeqe* is appreciated and consumed as a main meal, for fun as well as snacks by all ages, excluding babies. Further, 100% of the respondent were familiar with *Amaranthus* leaves but not its utilization in *Ujeqe* bread as a potential nutrient supplement. However, respondents indicated their willingness to try *Amaranthus* fortified-*Ujeqe* bread for improved food and nutrition security. Thus, *Amaranthus* fortified-*Ujeqe* bread can be explored for improved nutrient intake towards nutrition security in Empangeni area of KwaZulu-Natal province of South. Africa.

keywords: Food and Nutrition security, Indigenous, *Ujeqe,* Malnutrition, underutilized leave, supplementation.

5.1 Introduction

Malnutrition describes two conditions: nutrient-related excesses and micronutrient deficiencies (Maggini et al., 2018). Regardless of the form of malnutrition, the long-term negative impacts on humans are devastating because it reduces human life span since it is linked with morbidity and mortality. This can affect the productivity and economic development of a nation (Wijaya et al., 2021). Food security and nutrition security is crucial for sustainable well-being and so is a non-negotiable element of any productive nation. This can only exist when everyone always has the physical and purchasing power to acquire sufficient, safe, and nutritious food that meets people's dietary needs and food preferences that can support active and healthy life (FAO, 2008; Béné, 2020). Food security can only happen when it is conventionally considered in its entirety, meaning that it encapsulates the pillars of food security, including food availability, food accessibility, food utilisation, and stability or sustainability which aim to meet the human dietary needs for an active and healthy life (FAO, 2008). Nutritional security, on the other hand, refers to all people having access to and control over the physical, social, and economic means that ensure sufficient, safe, and nutritious food of preference to meet the dietary needs for a healthy life. South Africa is a nationally food secure country. However, there is a contradiction at the household level. Food base approach, including interventions like fortification of staple foods, has been suggested to target the larger population in curbing malnutrition challenges (Eggersdorfer et al., 2018). However, despite the interventions, malnutrition still lingers as one of the top health challenges across the globe, accounting for 820 million people suffering from a malnutrition-related illness (Grote et al., 2021). Globally, the impact of malnutrition is alarming as 1.9 billion adults worldwide are overweight and 462 million are underweight. A total of 41 million children under the age of five are overweight or obese, 159 million are stunted, and 50 million are wasted (WHO, 2020). Also, 528 million (29%) of women in their reproductive age around the world are affected by iron deficiency (resulting in anaemia) (WHO, 2020). One-third of all child deaths have been linked to malnutrition which contributes to more than half of children's death worldwide (Bain *et al.,* 2013). Even though malnutrition is rarely listed as the direct cause, child malnutrition has been linked to 54% of deaths in children in developing countries (Bain et al., 2013). Additionally, the coexistence of undernutrition such as stunting (low height for age), wasting (low weight for height), underweight (low weight for age) and over-nutrition (associated with over consumption of certain nutrients) has been linked to double or triple burden of malnutrition (Emmanuel and Babalola, 2022; Wijaya et al., 2021; Shrimpton and Rokx, 2012). Recently, the National

Department for Health, reported that 43% of children below the age of five are malnourished (stunting [27%], wasting [3%] and overweight [13%]), while 68% of women in South Africa are considered overweight (Emmanuel and Babalola, 2022). The highest prevalence of malnutrition is reported in Asia and sub-Saharan Africa (SSA). Although South Africa is considered as a nationally food secured country, this is not always the case at a household level (Arndt et al., 2020; Ogundeji, 2022).

Food insecurity is prevalent, especially among the rural population of many resource developing countries including South African rural communities (Calloway et al., 2022). Besides other underlying factors, the prevailing issues of poverty, hunger, problems with accessing safe, nutritious food, and financial incapacitation are major causes of food insecurity (Ogundeji, 2022; Cele and Mudhara, 2022). Moreover, many households are unable to afford or access enough safe and nutritious foods, especially meat, legumes, fresh fruits, and vegetables (Calloway et al., 2022). Instead, these essential sources of nutrients are being replaced with foods and drinks with high sugar, fat, and salt since they are cheaper and more readily available (Masipa, 2017; Rahaman et al., 2021). Additionally, the COVID-19 pandemic has compounded food security issues, furthering the increased vulnerability to food insecurity, especially among the poorly resourced countries and the less-privileged (Nugroho et al., 2022; Grote et al., 2021). Furthermore, the global recession has disrupted the global food supply chains which makes it more challenging to cater for large food imports of some countries especially countries of SSA (Grote et al., 2021). Therefore, finding the right balance between food and nutrition security, especially at the household level, is a global challenge. Measures to address food insecurity and malnutrition via value-adding utilisation of nutrient-dense food materials such as *Amaranthus* leaves to deliver essential nutrients to nutrient deficit food such as wheat bread to the consumers, is imperative (Tavakoli et al., 2016).

Wheat (*Triticum aestivum L.*), from the grass family, is a cereal grain widely cultivated for its seed and rated as the second most important top three world food crops following rice and maize (Miransari and Smith, 2019). Wheat has been identified as the most important food security crop even at the global level, with a production of 750 million tons on a total of 220 million hectares (Li et al., 2018). Africa produces more than 25 million tons of wheat on 10 million hectares while SSA produced a total of 7.5 million tons on a total land area of 2.9 million hectares accounting for 40% and 1.4% of the wheat production in Africa and at global levels respectively (Tadesse et al., 2019). In Africa, South Africa is one of the main wheat-producing countries, with its highest production in the Western Cape province (Tadesse et al., 2019; Theron et al., 2021; Li et al., 2018). Wheat has been identified to have a wide range of applications in the modern food industry (Singh et al., 2008). It is an essential ingredient in the preparation of many cereal-based foods, including noodles, biscuits, cookies, vetkoek *Amagwinya* (deep-fried dough), cakes, and bread of all types (*Qumbisa et al.*, 2020). Wheat flour, sugar, and salt constitute the main raw materials for different types of bread, including *Ujeqe* (Atuna et al., 2020; Wolgamuth et al., 2022). Bread is among the foods that mostly represent identity and traditions and which most often carries religious or other symbolic meanings (Wolgamuth et al., 2022). Wheat is considered a good source of energy, protein, minerals, B-group vitamins, and dietary fibre (Čurná and Lacko-Bartošová, 2017). However, consuming wheat-based food products like *Ujeqe* alone has been considered inadequate in regard to obtaining sufficient essential nutrients (Olagunju and Ifesan, 2013; Qumbisa et al., 2020; Cakmak and Kutman, 2018).

Ujeqe is made from wheat and well liked in eMpangeni KwaZulu-Natal, South Africa. It can be considered a strategic food product for essential nutrient supplementation, especially among malnourished populations. Malnutrition is a global health challenge that has prevailed over time (Eggersdorfer et al., 2018). A food-based approach where nutrient dense food materials are applied to staple foods has been identified as cost-effective and sustainable in tackling malnutrition, especially at the household level. Although thousands of plants are reported as food plants, only a few have been utilised as food in human nutrition, while others, such as the *Amaranthus* species are underutilised. Despite the potential and function of *Amaranthus* in human nutrition, it is underutilised. Its underutilisation is linked with its negative association with traditional preferences, attitudes, and consumer perceptions (Qumbisa et al., 2020). *Amaranthus* spp. As a functional foods plant, is endowed with essential vitamins, minerals, bioactive compounds, and phytochemicals that can be supplemented as essential nutrients in nutrient-deficient staple food, especially cereal-based food products like *Ujeqe* (Aderibigbe et al., 2022). However, with the abundance of literature on food fortification, no research on essential nutrient supplementation of *Ujeqe* bread by *Amaranthus* leaves has been reported. The investigation of essential nutrient supplementation of *Ujeqe* bread by *Amaranthus* leaves could provide insight into value adding to food for food security. Consumption of indigenous bread types like *Ujeqe* is appreciated in many localities (such as Empangeni) of South Africa more than conventional bread. Essential nutrient fortification of *Ujeqe* steam bread could improve nutrient intake of eMpangeni locality. Therefore, this study assessed the potential utilisation of *Amaranthus* leaf as nutrient fortification agent in *Ujeqe* steam bread.

5.2 Materials and methods

An integrated design was utilised; this design enables the collection and processing of data using both (quantitative and qualitative) research methods in a single study (Creswell, 2011; Ghasempour et al., 2014). Purposive convenience random sampling was utilised to sample 100 participants. Semi structured questionnaires were used to gather data. A total of 91 filled questionnaires were returned and analysed. The researcher interviewed four key informants to gain insight into how traditional *Ujeqe* is prepared as well as the locals' perceptions of *Amaranthus* as a supplement in *Ujeqe* in the study area.

5.3 Description of the study area

This section is detailed in Chapter 3, section 3.5.

5.4 Data analysis

Data were processed using Origin software (9.0), and the results were presented in percentages and frequencies on pie charts and bar graphs. The key informants' information was analysed using descriptive narrative content analysis.

5.5 Ethical clearance

This section is detailed in chapter 3, section 3.15.

5.6 Results and Discussion

5.6.1 Participant's demographic information

The demographic information of participants in the study are presented in Figure 5-1a-e. Figure 5.1a shows that 75.31% of the respondents were females and 24.69% were males, which is similar to study about smallholder farmers in rural communities (Ndlovu et al., 2021). Figure 5.1b shows that age ranged between 18 and 70 years, with 40.74% percent of the respondents being below the age of 26. Figure 5.1c, reveals the educational level of the respondents with 54.32%, 35.8%, 6.17% and 3.70% of the respondents being people with informal education (mainly self-employed businessmen and women), primary education, secondary education, and tertiary education, respectively. Figure 5.1d further elucidates the employment status of participants in the study area. The employment distribution shows that 49.98% are unemployed, 41.38% are self-employed, and 9.11% are employed (7.41% are employed in the private sector and 1.7% in government). These results reveal the common characteristics of many developing countries including South Africa. The unemployment status of underdeveloping countries is reported to be high, especially in rural communities, accounting for the high rate of malnutrition in rural communities (Ngema et al., 2018; Filmer and Fox, 2014). The study demographic (Figure 5-1e) also reveals that 100% of the respondent were black Africans. This agrees with another study on Empangeni demography. A study by Lehohla (2004) reported the Empangeni population to be mostly black Zulu-speaking Africans.

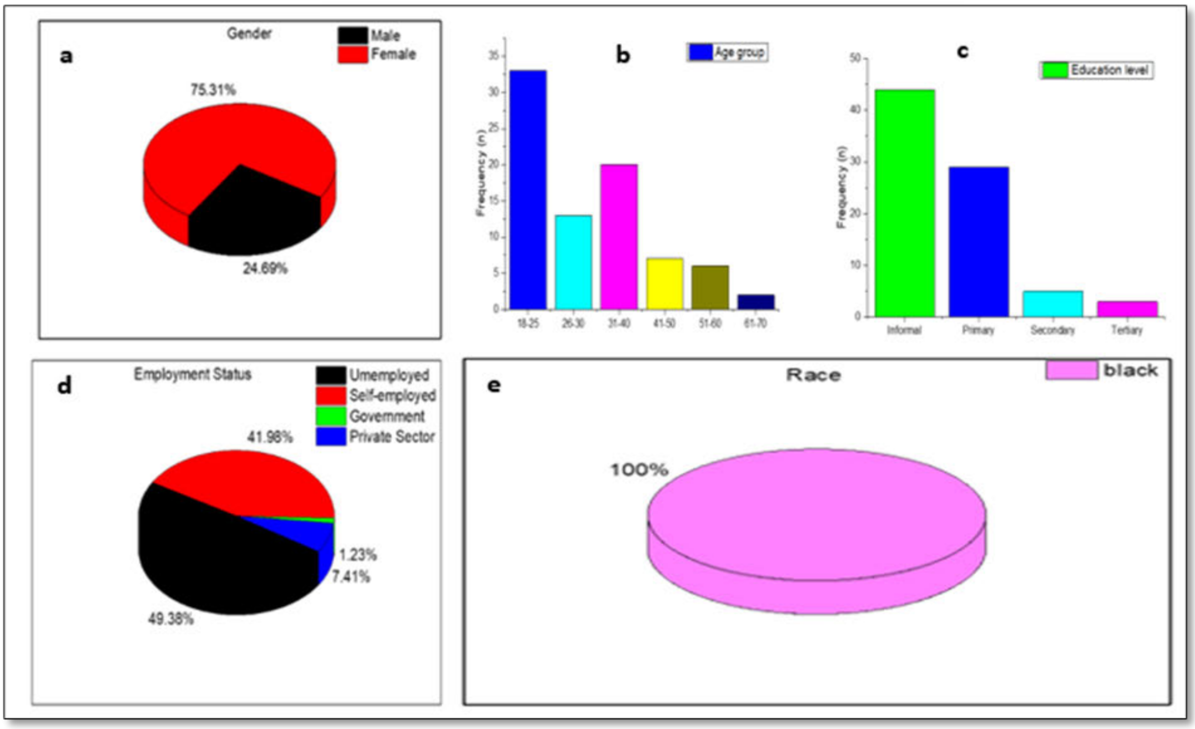

Figure 5-1: Respondent demographics showing: 5.1a) Gender, 5.1b) Age group, 5.1c) Education level, 5.1d) Employment status, and 5.1e) the race distribution of respondents

5.7 Traditional preparation of *Ujeqe* bread in eMpangeni

Findings from this study revealed that traditional *Ujeqe* bread is prepared by firstly estimating the different ingredients (flour, yeast, a little salt, a little sugar, a little butter or oil, warm water, and milk). The components are combined in appropriate quantities to obtain a soft elastic dough. The dough is placed in the sun or kept in a warm place to undergo fermentation for at least 40 minutes. It was identified that temperature is a significant factor in the making of *Ujeqe* bread. The fermentation period may therefore be extended from 40 minutes to an hour or more on a cold day. The desirable time is confirmed by a visible rise in the dough size. The risen dough is collapsed and kneaded a the second time and placed into a plastic bag or large container that will be used for the steaming process. The dough is allowed to rise for another 40 minutes before placing in a big pot of boiling water with a close lid and the dough is cooked for an hour. The steamed *Ujeqe* bread is confirmed to be cooked when a skewer or a knife comes out clean after its insertion. The prepared *Ujeqe* bread (Figure 5-2) is ready to be served alone or with some complimentary foods.

Figure 5-2: Picture of regular *Ujeqe*

5.8 Consumption of *Ujeqe* bread in Empangeni

All the participants (100%) (Figure 5-3a) were familiar with Ujeqe, and 92.59% of the participants (Figure 5-4b) of the respondents agreed that *Ujeqe* bread is regarded as an indigenous food in the Empangeni community. Additionally, all of the informants (100%) indicated that *Ujeqe* bread is consumed by all age groups. The reasons for informant's consumption of *Ujeqe* include *Ujeqe* is an indigenous food (one of the most appreciated foods on the family's menus), is a filling food that provides the consumers with desirable energy, can be served any time of the day, and the preparation is easy. This study is consistent with the study reported by Touyarou et al. ((2012). Moreover, it is appreciated and consumed for fun as well as snacks by all ages, excluding babies. In addition, *Ujeqe* is a regular food served during special occasions and ceremonies like weddings, and religious and traditional rites. For instance, some participants confirmed that *Ujeqe* is a food usually served to observe Sabbath day, buttressing the fact that *Ujeqe* is used for religious rites. An interviewee added that traditionally, it is believed that *Ujeqe* bread should be food that is naturally cooked without modern food additives like spices. Hence, it is a preferred indigenous food, especially when served with *Usu* (offal meat). From the study, it is obvious that the nutritional content of *Ujeqe* bread is not considered as one of the reasons for its consumption. Also, this study revealed that *Ujeqe* bread is sometimes the only food option on some household menus for the day. Such attitudes toward dietary lifestyles can predispose the individual to nutrient deficiency challenges. This implies that nutritional knowledge of cereal-based food, including *Ujeqe* bread, is lacking among the rural populace. Although traditionally, *Ujeqe* bread is consumed with protein-rich foods like *Usu* (offal meat) chicken and beans, not everyone has access to the protein foods as *Ujeqe*'s complementary foods; hence, *Ujeqe* bread is sometimes consumed without these complementary foods by many households.

Long-term consumption of foods that are limited in essential nutrients, including *Ujeqe* bread, could predispose the consumer to nutrient deficiency challenges. Also, the notion that *Ujeqe* bread is a "healthy food" shows a lack of nutritional knowledge regarding *Ujeqe* bread by the participants. Although *Ujeqe can* provide lots of calories and energy for consumers, studies have shown that cereal-based foods are limited in essential nutrients. Hence, it is considered inadequate to meet the daily dietary needs for optimal well-being, especially when consumed as a sole source of nutrient. Therefore, supplementing *Ujeqe* with nutrient-dense food vegetables like *Amaranthus* cannot be overemphasised.

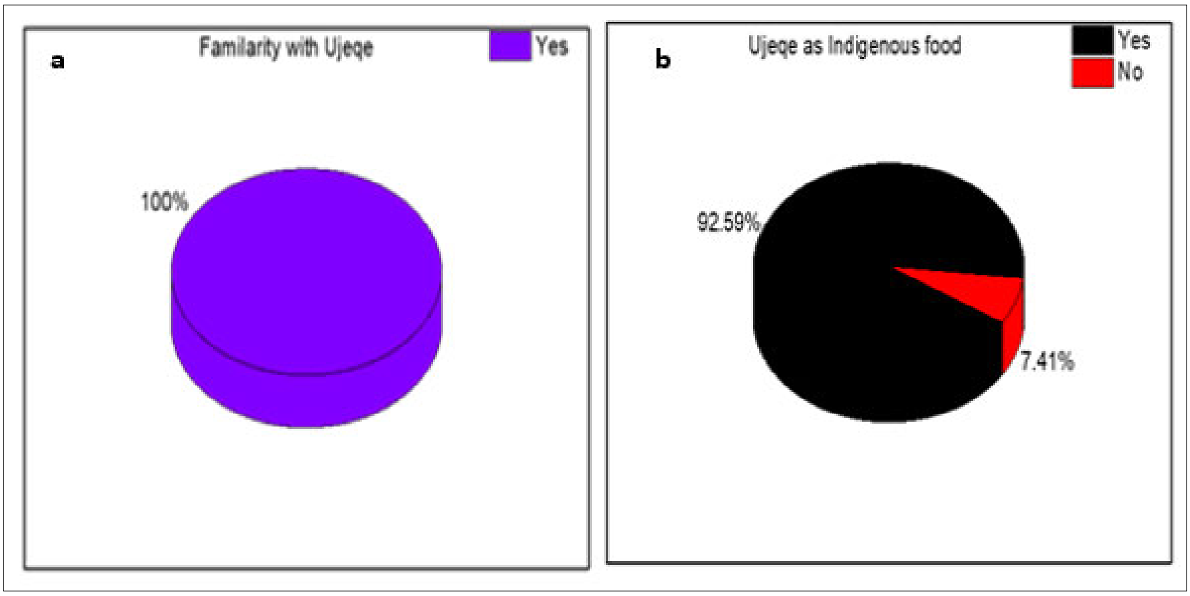

Figure 5-3 a & b: Respondent's familiarity and consumption of utilisation of *Ujeqe*

5.9 *Amaranthus* leaves as a complementary nutrient source in *Ujeqe* bread

Figure 5-4a shows that 98.77% of participants consume the fresh form of *Amaranthus* leaves and 1.23% consume the root. Figure 5-4b represents the frequency of both adults and children regarding *Amaranthus* consumption in households. This shows that both children and adults consume *Amaranthus,* a desirable observation. Children, especially between ages 1 to 5, have shown a low intake of vegetables, especially leafy ones (Bucher et al., 2014). This is mostly because many of them within such groups are considered picky eaters. Figure 55b reveals that

96. 3% consume the green leafy *Amaranthus* whereas 3.7% consume the red Amaranth which is commonly known as purple Amaranth. Green leafy *Amaranthus* including *Amaranthus spinous* and *Amaranthus cruentus* species are the most sold variety in the study area, even though several species of *Amaranthus* have been reported (Peter and Gandhi, 2017). However, respondents can only identify the species by their colour and perhaps their mode of propagation. Thus, irrespective of the species grown in the study area, they are either known as red or green *Amaranthus*. However, *Amaranthus spinous* are neglected because they are being considered as the less privileged food or as feeds for animals.

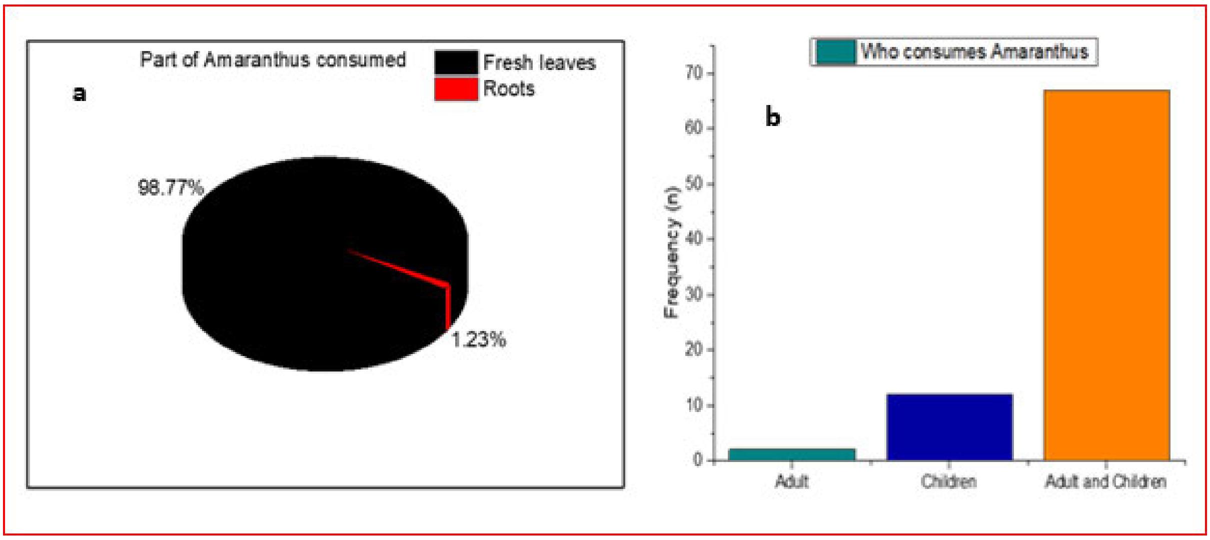

Figure 5-4 a & b: ***Amaranthus*** **consumption (a), Household consumption of** ***Amaranthus leaves***

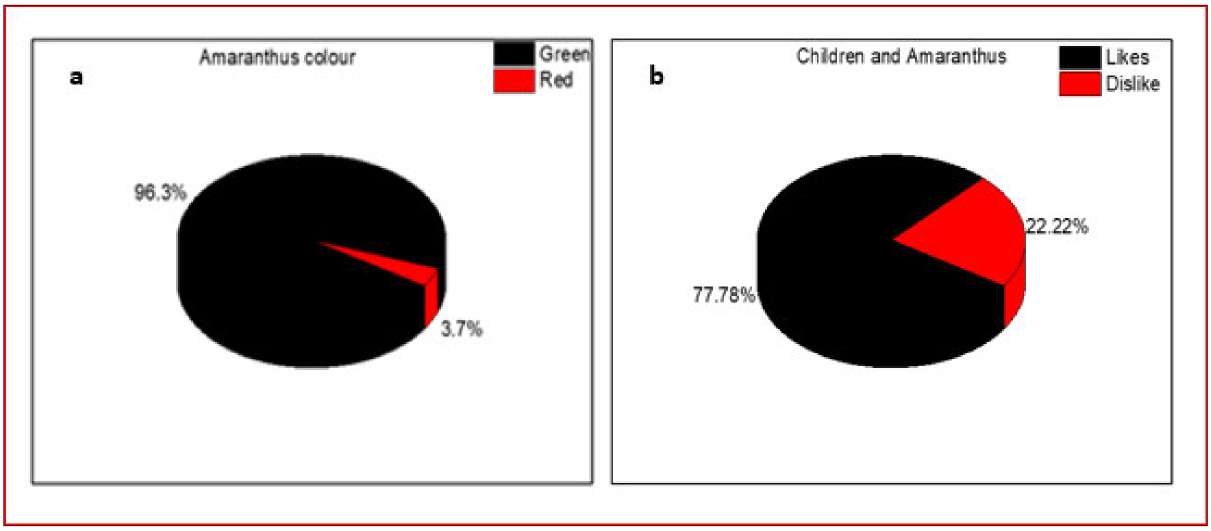

Figure 5-5: Colours of ***Amaranthus*** **consumed (a), Children's disposition to** ***Amaranthus*** **(b)**

About 46.91% of the respondent do not consume *Amaranthus* seeds and 11.11% (Figure 5-7a) do not know if *Amaranthus* seeds are consumed as food. Literature reports *Amaranthus* seed known as pseudo cereal has been utilised in various forms as food in other parts of the world. This could be because of the knowledge gap regarding *Amaranthus* seed and its nutritional benefits. Figure 5-7b reveals that most of the respondent throw away the seed of *Amaranthus,* while others (Figure 5-7b) save the seed for the next planting season. The observation in this study is consistent with other studies on *Amaranthus* seeds which reported that most African countries do not consume *Amaranthus* seeds and usually throw them away (Ogwu, 2020, Ruth et al., 2021).

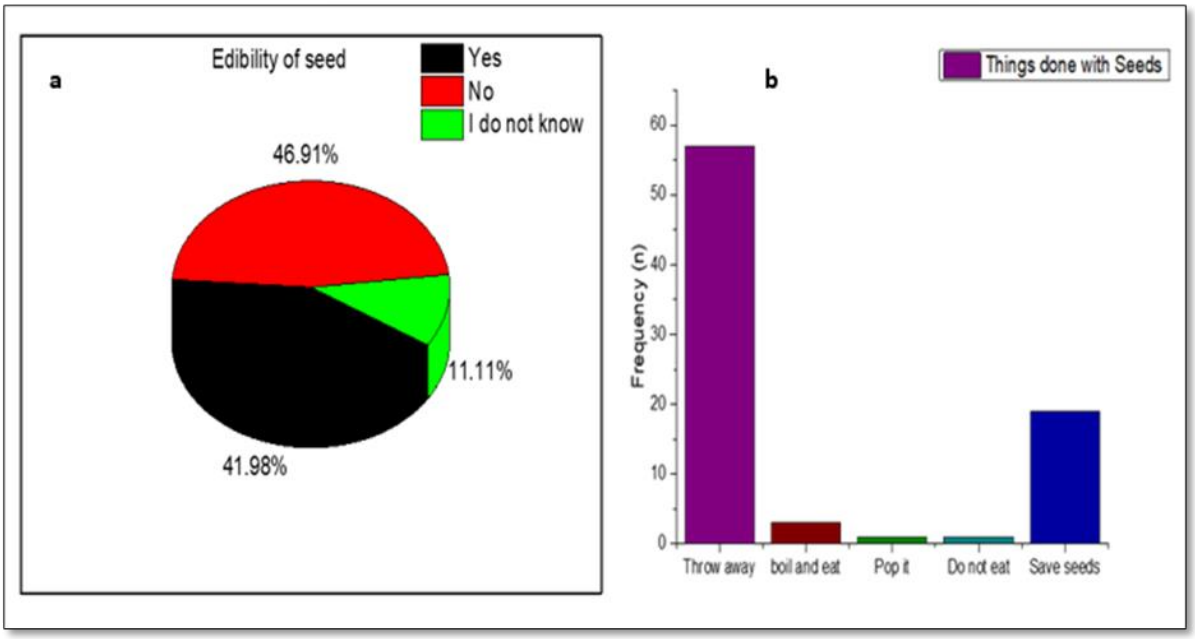

Figure 5-6: Edibility of amaranth seed (a), What done with amaranth seeds (b)

5.10 *Amaranthus* fortified *Ujeqe* bread

In Figure 5-7a shows that 100% of the respondents agreed that the part of the *Amaranthus* plant they consume is the leaves, while Figure 5-8b shows the frequency of *Amaranthus* consumption. The lowest rate of *Amaranthus* consumption is daily consumption. This study reveals that even though *Amaranthus* are nutrient-dense vegetables and indigenous to the Empangeni community, they are being underutilised in the study area (Kwenin et al., 2011; Morris *et al.,* 2018). This is similar to reports on the low consumption of indigenous leafy vegetables like *Amaranthus* in rural communities (Morris et al., 2018; Qumbisa et al., 2020), but not in agreement with World Health Organization (WHO) recommendations on nutritional food consumption. The WHO encourages the consumption of leafy vegetables including *Amaranthus* as a possible solution to micronutrient deficiency health challenges (Olusanya, 2018).

Figure 5-8c shows that 71.6% of the respondents indicate their willingness to consume *Ujeqe* food products supplemented with *Amaranthus* leaf powder for nutritional benefits and health reasons, while 28.4% of the respondent were indifferent about the consumption of *Amaranthus*-supplemented *Ujeqe* bread. The respondents were very familiar with *Ujeqe* and consume *Ujege* bread mainly because it is their indigenous food, not as a nutrient source. However, their opinion that *Ujeqe* has "health benefits" is probably because it provides energy for their day-to-day activities. A diet composed mainly of wheat, such as a cereal-based food like *Ujeqe* bread, can predispose the vulnerable to nutrient deficiency challenges. Regular consumption of *Ujeqe* as a sole meal without complementary nutrient-dense food sources such as *Amaranthus* can render one at risk of nutrient deficiency health hazards (Qumbisa et al., 2020). In Figure 5-7c, for instance, an informant disliked the idea that *Amaranthus* does complement *Ujeqe* bread nutrient-wise. Similarly, six respondents said they are not sure that they would like to eat *Ujeqe* bread supplemented with *Amaranthus* leaf powder. Others revealed that carrot has been utilised as an ingredient in *Ujeqe* bread because of its nutritional value. On the other hand, some are willing to try something different, especially for health reasons, therefore, they are happy and comfortable trying *Ujeqe* bread supplemented with *Amaranthus.*

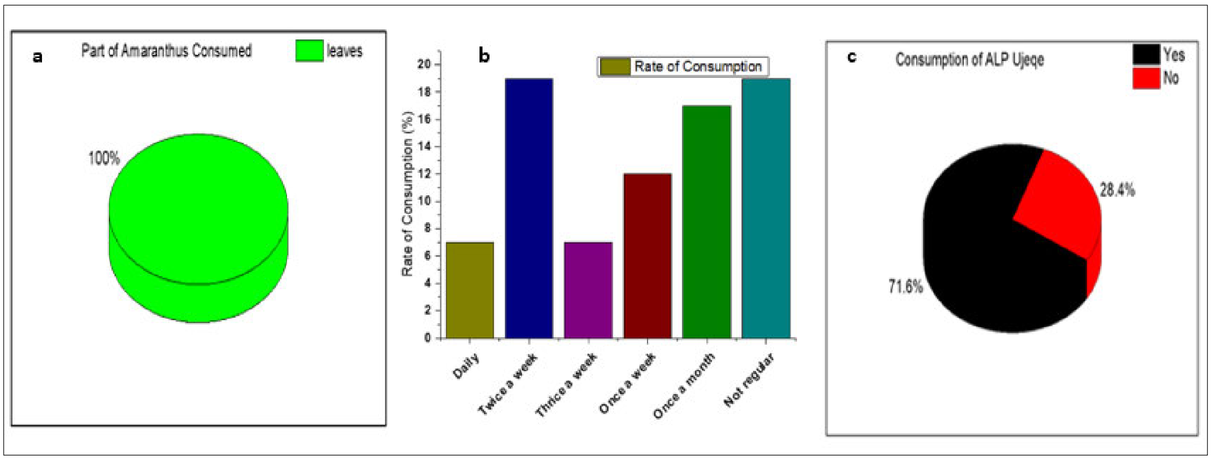

Figure 5-7. Parts of *Amaranthus* consumed (a), Rate of *Amaranthus* consumption (b), Willingness to consume *Ujeqe* supplemented with *Amaranthus* leaf powder (c)

5.11 Conclusion

This study reports the perceptions and the utilisation of *Ujeqe* and *Amaranthus* as potential food supplements for improved food security in Empangeni KwaZulu-Natal, South Africa. *Ujeqe* is identified as a traditional wheat-based steamed bread, and is well in the Empangeni community in KwaZulu-Natal, South Africa. *Ujeqe* is a staple food consumed by all age groups except infants. This study enumerates the ingredients and the traditional method of preparing Ujeqe in the study area, alongside reasons why *Ujeqe* is appreciated in the study area. These reasons include its ease of preparation and ability to be consumed at any time. It is a food served in traditional ceremonies, including weddings and during religious and ancestral worship. Complementary food for *Ujeqe* identified during the study was mainly protein-rich, including beans, chakalaka, meat, and *Usu* offal meat. However, not everyone is privileged to access these complementary foods. Thus, the marginalised consume *Ujeqe* alone. *Amaranthus* is considered a nutrient-dense indigenous plant and is cheap and accessible to community members. However, it has not been used as a food ingredient in *Ujeqe* bread. The findings of this study show that community members are willing to consume *Amaranthus*-supplemented *Ujeqe* for health purposes. Therefore, there is a need for more awareness of the potential of *Amaranthus* leaves and their inclusion in staple foods, including *Ujeqe* steamed bread. *Amaranthus* leaf-supplemented powder *Ujeqe* can be developed, and its consumer acceptability be assessed for improved food and nutrition security in rural communities. Also, the cultivation, processing, and commercialisation of Amaranthus should be promoted in rural communities for enhanced food and nutrition security.

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CHAPTER 6

Mineral composition and consumer acceptability of *Amaranthus* leaf powder supplemented plain wheat flour *Ujeqe* for improved nutrition security.

This Research chapter has been prepared for publication by Olusanya N. Ruth[1*], Kolanisi Unathi[1,2], and Ngobese Nomali[3], with the title: Mineral composition and consumer acceptability of *Amaranthus* leaf powder supplemented plain wheat flour *Ujeqe* for improved nutrition security (Published in FOODS -MDPI Journal) and presented in the following pages.

CHAPTER 6: MINERAL COMPOSITION AND CONSUMER ACCEPTABILITY OF *AMARANTHUS* LEAF POWDER SUPPLEMENTED UJEQE FOR IMPROVED NUTRITION SECURITY

Research paper published in Foods MDPI (https://doi.org/10.3390/foods12112182)

Abstract:

Malnutrition, especially micronutrient deficiency, is a widespread health challenge that predominantly affects young children, young ladies who are within the productive age, refugees, and older adults who reside in rural communities and informal settlements in underdeveloped and developing countries. Malnutrition is caused by consuming either too little or too much of one or more food nutrients. Additionally, monotonous dietary lifestyle especially the over reliance on staple foods, is identified among top factors limiting many individuals' intake of essential nutrient. Thus, enriching starchy and cereal-based staple foods including Ujeqe (steamed bread) with fruits and especially leafy vegetables is being suggested as a strategic medium for essential nutrient delivery to malnourished population and including Ujeqe regular consumers. Amaranthus, called pigweed, has been rediscovered as a nutrient-dense multipurpose plant seeds have been explored as nutrients enhancers in staple foods however, the leaves are underutilized especially in Ujeqe. This study aims to enhance the nutritional mineral content of Ujeqe. An integrated research approach was used where Amaranthus dubius was self-processed into leaf powder and Amaranthus leaf powder (ALP) and the ALP-supplemented wheat flour Ujeqe prototypes 0%, 2%, 4%, and 6% were investigated for their mineral composition. Sensory evaluations of enriched Ujeqe were conducted using 60 panellists on a five-point hedonic scale. Findings show that the moisture contents of the raw materials and the supplemented prototypes were low, indicating a good self-life of the food ingredient before used for Ujeqe development. Carbohydrates of raw materials ranged from 41.6–74.3%, fat ranged from 1.58–4.47%, Ash ranged from 2.37–17.97%, and protein ranged from 11.96-31.56%. Also, fat, protein, and ash content had significant differences at ($p<0.05$). The moisture content of enhanced Ujeqe was equally low connoting keeping quality of the sample. The increase concentration of ALP led to an enriched Ujeqe especially in the Ash and protein content. Similarly, Calcium, Copper, potassium, Phosphorus, Manganese, and Iron content were significantly influenced at ($p<0.05$); 2% ALP-supplemented Ujeqe was the most acceptable prototype as the control sample, 6% was the least preferred prototype. Although ALP dubius can enrich staple foods including (Ujeqe) however this study declared that higher addition of ALP dubius leads to low consumer acceptability rate of the Ujeqe which is not statistically significant. Amaranthus is an economical source of fibre which was not investigated in the study. Therefore, further studies can explore the fibre content of the ALP-supplemented Ujeqe.

Keywords: - Amaranthus dubius leaves; nutrient enhancement; Nutrition security; Zulu bread; sensory evaluation

6.1 Introduction

Worldwide, people eat a lot of varieties of cereal-based meals as staples, particularly wheat-based foods that include *Ujeqe*(steamed bread) (Vrancheva et al., 2019, Atuna et al., 2020). Wheat flour is the major ingredient for bread production, including *Ujeqe*, which may contain a wide range of nutrients, especially carbohydrates, for human functioning(Serna-Saldivar, 2016, Odunlade et al., 2017, Carocho et al., 2020). However, refined wheat-based foods lack dietary fiber and other essential macro and micronutrients); thus, wheat is primarily considered as good energy source with limited essential nutrients(Odunlade et al., 2017, Vrancheva et al., 2019). This underpinned the reason behind the current, increased consumer demand for healthy and nutritious foods world. Therefore, peoples need for healthy and nutritious food can still be attained via the people' food of preferences but through nutrient enrichment of staple foods. Hence, tackling malnutrition has led to the increased interest in studies exploring available nutrient-dense plants that are underutilized, including functional food materials like *Amaranthus* leaves(Kwenin et al., 2011, Morris et al., 2018, Sarkar et al., 2022). Hence, most studies are geared towards adding value to staple food to tackle the world's food and nutrition insecurity, which are pandemic among malnourished population living in rural settings or disadvantaged communities across the world. The motivation of this studies revolves around the demand from the United Nations (UN) which set some sustainable development goals that the human population must pursue (Bolarinwa et al., 2019). Among the 17 goals set for agenda 2030 include " (1) production, (2) adequate consumption and (3), " human wellbeing and good health which are to be pursued as goals, respectively) (Tolve et al., 2021). In this regard, the division between economic growth and environmental depletion and the need to enhance efficiency in resources that will promote sustainable lifestyles especially people's dietary lifestyles are hereby credited to be the starting point and focus of any eco-friendly consumption and production of food(Tolve et al., 2021). Previous studies, shows that cereals have been investigated as sources of staple foods. wheat, being a cereal, have been used to produces several wheat-based food products have been made from plain flours and a composite flour to make foods, that include variety of different white bread like *Ujeqe*, as the most widely consumed food in many regions of the world including South Africa(El-Gammal et al., 2016, Huang and Miskelly, 2016, Atuna et al., 2020). Inadequate consumption of foods that are more of quantity and not quality; a monotonous diet of cereals and starch-based foods has been identified as factors contributing to malnutrition which is identified as a public health challenge(Dukhi, 2020). These challenges are preventable and curative where a conscious and sustainable intake of di-versified nutrient dense foods is intentionally consumed. The consumption of vegetable especially the indigenous leafy greens is globally low; even in South Africa(Sarkar et al., 2022). Hence, their potentials to provide food and nutrition security to the most vulnerable group has not been maximally explored. Currently, malnutrition still affects young children, young ladies who are within the productive age, refugees, and older adults living mostly who resides in rural communities and informal settlements in underdeveloped and developing countries(Qumbisa et al., 2021, Wijaya et al., 2021). *Ujeqe* is in a refined wheat-based food products that is well appreciated by all South Africans excluding babies. It is precisely appreciated among the Zulu ethnic group (Olusanya et al., 2022). *Ujeqe* complimentary foods are protein-based foods like offal meats and chicken. However, not all people in the rural community access these complimentary foods(Olusanya et al., 2022). The sole consumption of wheat-based food product including *Ujeqe* without fruits and vegetables is limited in essential nutrient(Qumbisa et al., 2021). Therefore, supplementing cereal-based staple foods like *Ujeqe* is suggested as vital medium for essential nutrient delivery especially for the nutrition security of regular consumers of inadequate foods including *Ujeqe*. Previous studies maintains that *Amaranthus* is a C4 fast-growing plant; and is widely distributed across the world. *Amaranthus* belongs to the family *Amaranthaceae* having about 70 species of *Amaranthus* , of which 17 are grown for edible leaves, and 3 are cultivated as food grains(Achigan-Dako et al., 2014, Sarker et al., 2020). However, a few species of the *Amaranthus* are used as a traditional medicine hence, studies shows that *Amaranthus* is an economic and sustainable source of plant with essential nutrients for food and nutrition security which considers the quality of foods and not just quantity that being ingested(Simelane and Worth, 2020). Although *Amaranthus* is a neglected plant however, it has been rediscovered as one of the most promising plant genera that contains essential nutrients with phytochemicals, bioactive compounds, and various other valuable(Achigan-Dako et al., 2014, Qumbisa et al., 2021). The grain of *Amaranthus* have be used for the fortification of staple foods but, the leaves has often been neglected as supplements or fortificants (Ruth. N. Olusanya et al., 2021). Hence, there is scarce information on the use of the most available underutilized green leafy vegetables like *Amaranthus* as nutrient enrichment especially in *Ujeqe*. This study therefor, investigates (*Amaranthus dubius*) as nutrient enhancer and sustainable food ingredient to alleviate food and nutrition insecurity of persons in malnourished regions(Ruth. N. Olusanya et al., 2021). Cereal-based food improvements have been explored via fortification with nutrient-dense plants like moringa leaves, seeds, and other nutrient-dense plant materials that are available and easily accessible have been investigated in staple food However, *Amaranthus* leaf powder is scarcely utilized, especially in *Ujeqe* steamed bread; there-fore, this study explored an innovative attempt to enrich *Ujeqe*, a traditional (steamed bread), for the first time.

6.2 Materials and methods

6.2.1 Research design

The aim of this study is to investigate the effects of *Amaranthus dubius* leaf pow-der on the nutritional composition of *Ujeqe*.

An integrated research design comprises qualitative and quantitative data collection was considered appropriate for this study. A purposive convenient random sampling technique was used for population sampling for the sensory evaluation. About 4 to 6 key informant interviews was conducted according to methods described by Muellmmnn have been recommended for face-to-face key informant interviews (Muellmann et al., 2021). Thus, a face-to-face interview was conducted in the study area using six key inform-ants who are regular consumers of *Ujeqe* were interviewed(Muellmann et al., 2021). During the qualitative study, the key informant interview was employed to have insight into the ingredient and traditional method of preparing *Ujeqe*, which was adopted for this study. An experimental study was explored in a standard food laboratory (Consumer Science department) at the University of Zululand KwaZulu-Natal Province Republic, South Africa. During this investigation, several trials of scaling up and down of ingredients were explored, and a standardized recipe for both the control sample and *Amaranthus* leaf powder (ALP)-supplemented prototypes of *Ujeqe* were developed.

6.2.2 Sources of materials, equipment used to produce ALP supplemented *Ujeqe.*

The *Ujeqe*, ingredients for this study were purchased from Shoprite at Esikhawini Empangeni, South Africa. These ingredients include (golden cloud white bread wheat flour), sunflower oil, Hallett white sugar, gold star instant yeast (finest quality), and iodized sea salt. All ingredients were stored separately in an airtight storage box in a refrigerator (4°C) until it was used. *Amaranthus dubius* leaves were purchased from local vendors at the station market in Empangeni KwaZulu-Natal, South Africa. They were processed into *Amaranthus* leaf powder (ALP) according to the description in figure.1.

Similarly, the equipment used in this study includes a Combi-master oven fan, dryer, and electric stove. UK., 0.05mm sieve, stainless still colanders, and electric blender (Wz-Q10S, Multifunctional speed blender. China). Medium stainless pot stain-less bowls, digital weighing scale, and foil paper. *aQuelle* natural spring still water, ceramic bowls and saucers, serviette, disposable cups, and five-point pictorial smiling face hedonic scale as described in the Appendix B and C.

6.2.3 Description of the study area

Empangeni's geolocation is 28° 44' 50.3868' 31° 54' 42.'7078'it is located 160 km away from Durban along the R34 off the N2, KwaZulu-Natal, South Africa. It is positioned in the hilly countryside of the uThungulu district with hot, sticky, and languid days. Empangeni's major crops are cotton, timber, and sugarcane plantations. It is also known for cattle-rearing activities (SAHO, 2017). It was initially the location of the Norwegians Mission station, founded near the stream called Empangeni, which was later moved to Eshowe(SAHO, 2017). The name 'Empangeni' comes from a Zulu word called 'pangaed', which means 'grabbed,' and it refers to the number of crocodile attacks on water bearers in the nearby Empangeni stream(SAHO, 2017).

6.2.4 Production of *Amaranthus* leaf powder

The *Amaranthus* leaf powder was self-processed, according to Qumbisa.(2021),(Qumbisa et al., 2021). following the procedure in the next subtopic described in the flow chart diagram in Figure 6.1.

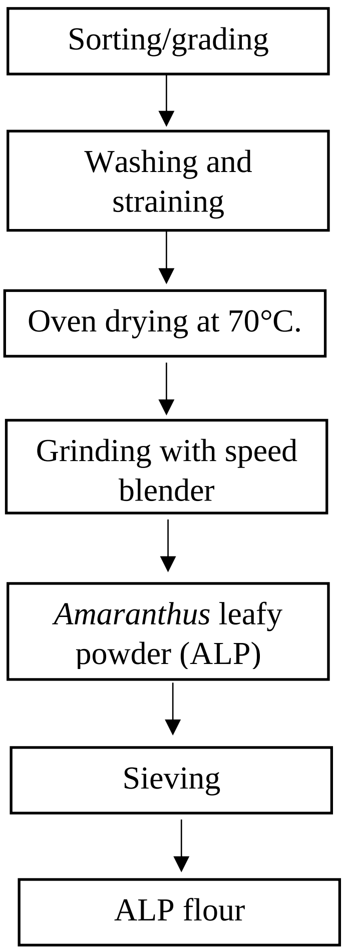

Figure 6-1: Flow charts for processing of *Amaranthus* dubius leave to *Amaranthus* leaf powder (ALP)

Amaranthus dubius leaves described in Figure 6.2. were sorted, graded, and washed severely under running tap water. This whole process of sorting and grading eliminated the dirt that comes with the *Amaranthus* leaves. To get rid of contaminants from agricultural processes that may come along with the *Amaranthus* leaves, two teaspoons of salt were dissolved in 2 L of tap water. They were used to wash the *Amaranthus* leaves, after which the leaves were rinsed thrice to remove any excess salt(Qumbisa et al., 2020). The washed *Amaranthus* leaves were placed in a strainer for a few minutes to get rid of removal of excess; After the draining of the excess water, the *Amaranthus* was dried in a combi oven fan dryer at 70˚C for 2 hours (Qumbisa et al., 2020). The dried leaves were milled into a fine powder using an electric blender (Wz-Q10S, Multifunctional Blender). To obtain a uniform *Amaranthus* leaf powder (ALP), the grounded ALP was sieved through a sieve of 0.05 mm, which was packed into airtight, labelled zip-lock plastic bags until it was used for the production ALP-supplemented *Ujeqe*.

Figure 6-2: Cleaned *Amaranthus dubius* used for the processing of ALP

6.2.5 Production of standardized *Amaranthus* leaf powder supplemented Ujeqe (ALPSU)

An experiment was conducted to establish the effect of ALP on the mineral composition and consumer acceptability of *Ujeqe*. The ingredients in Table 6.1. were used to formulate a composite flour for ALP-supplemented *Ujeqe* prototypes. Plain wheat flour was substituted for *Amaranthus* leaf powder (ALP) at ratios of (0%, 2%, 4%, and 6%) were mixed with other ingredients bind with lukewarm water to formulate the dough described in Figure 6.3

Table 6.1: Recipe for wheat-based ALP supplemented *Ujeqe*.

Amaranthus %	PWF (g)	Yeast (g)	Sugar (g)	Salt (g)	Sunflower Oil (ml)	Water (ml)
0	100	3	10	1	7.5	60
2	98	3	10	1	7.5	60
4	96	3	10	1	7.5	60
6	94	3	10	1	7.5	60

[1]*Amaranthus* leaf powder (ALP)

[2]Plain wheat flour (PWF)

6.2.6 Production of *Amaranthus* leaf powder supplemented *Ujeqe* (ALPSU)

The control sample (0%, ALP) *Ujeqe* in Table 1. was prepared according to the traditional method adopted from the study site. Likewise, A standard recipe for ALP-supplemented prototypes was achieved after several trials of formulations in a food laboratory consumer science department at the University of Zululand Kwadlangezwa. The standardized recipe for the control sample and the ALP-supplemented *Ujeqe* recipe are described in (Table 6.0 1.). The development of *Ujeqe* food product starts with the formulation of a composite flour next the formulation of the 0% and ALP supplemented dough formulation. After which, (plain wheat flour and amaranth leaf powder at an increasing substitution level of 2%, 4%, and 6% ALP). All the dry ingredients of *Ujeqe* acquired were measured in bowl to obtain a composite flour. Lukewarm water was added to the blended flour to make an elastic soft round moulded-shaped dough (6%, 4% 0% and 2%) Figure 6.3. The dough was manually kneaded for 7 minutes. After which, the dough was covered with a kitchen napkin, and was allowed to ferment (proof) for 40 minutes. The fermentation or proofing was ascertained when the dough doubled in size. The *Ujeqe* fermented dough was punched to release the in-built air of the dough, after which the dough was moulded into a ball again and placed in a stainless bowl used for the steaming of the *Ujeqe.* The stainless bowl was covered with a kitchen napkin and allowed to be proof the second time for another 40 minutes. Finally, the stainless bowl was inserted into a large stainless pot of boiling water, and the *Ujeqe* dough is placed into the pot. The dough was not in direct contact with the water. Foil paper was used over the pot before the lid; this is to trap the steam and the dough was allowed to steam for 50 minutes on an electric stove. The pot was not open until after 30 minutes. A skewer was inserted to check if *Ujeqe* was cooked, and a well-cooked *Ujeqe* was determined; when skewer is inserted it came out clean. The ALP supplemented *Ujeqe* samples in the Figure 6.4. ALP *Ujeqe* was kept at room temperature to cool for one hour, after which it was thinly sliced and spread on trays and dried at room temperature [12]. The dried *Ujeqe* made into a crucible, were packaged into a labelled zip-lock bag, and was stored for 48 hours before analysis.

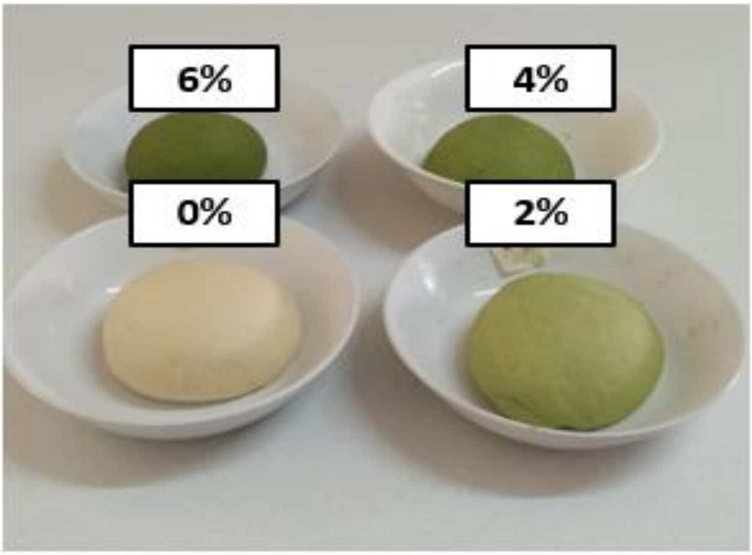

Figure 6-3: *Ujeqe* Dough obtained for the control and supplemented prototypes

The 0% dough implies the plain wheat flour that was used for the control sample; other Prototypes are *Amaranthus* leaf powder supplemented prototypes 2%, 4%, and 6% are supplemented in 3 types of ratios.

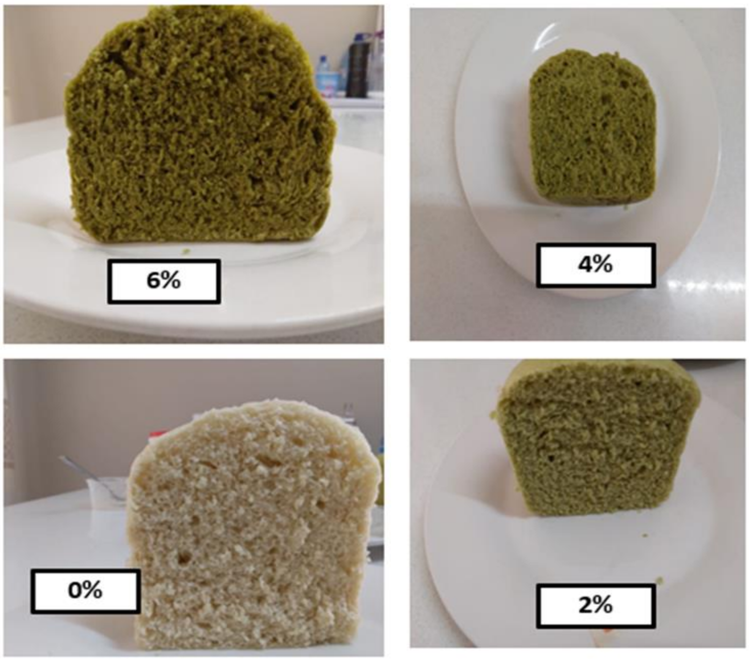

Figure 6-4: ***Ujeqe*** **ALP 0%, 2%, 4% and 6% ALP-supplemented** ***Ujeqe*** **prototypes**

6.2.7 Physical properties of Ujeqe dough and Ujeqe ALP supplemented food prototypes

The addition of *Amaranthus* leaf powder (ALP) to wheat flour led to a change of colour of the final dough (Figure 6.3.) changed from light green to dull green. Also, it was observed that an increased concentration of ALP resulted in a lesser elasticity of the dough of the supplemented *Ujeqe* dough. The physical property of ALP-supplemented *Ujeqe*

Figure 6.4 shows the four ALP supplemented *Ujeqe* prototypes. The increased concentration of ALP in the prototype resulted into a dense ALP-supplemented *Ujeqe.* The density of the *Ujeqe* may be appreciated by older people because they believe that the denser the *Ujeqe t*he more filling it will be. Similar results were reported when the addition of leafy vegetable powder like moringa oleifera was explored in wheat flour food products. There was a change of colour from light green to darker green. This was because of the green pigmentation in the *Amaranthus* leaves.

6.2.8 Nutritional Analysis of ALP Ujeqe food samples

The supplemented *Ujeqe* prototype was dried and processed into a powdered, crucible food material. The raw materials (PWF and ALP), the control food sample (0%), and the three ALP-supplemented prototypes (2%, 4%, and 6%) were packaged in triplicate into an airtight zip-lock plastic bag for Nutritional Analysis. Following the analysis, in this study, all the proximate content of the food samples (moisture, Protein, Fat, Ash). The content of the crucible food samples was analysed according to the AOAC Official Method 934.01 (AOAC, 2003). (Nancy and Wendt, 2003) Whereas the following equation was used to calculate the percentage of protein in the *Ujeqe* prototypes: % crude protein = % N × 6.25. The Carbohydrate content in the food samples was determined by difference; that is, (100 minus the total percentage of % Protein, % Moisture, % Fat, % Ash). The mineral content of the *Ujeqe* prototypes was determined as Ash according to the AOAC official method 942.05 (AOAC, 2003)(Nancy and Wendt, 2003).

6.2.9 Data analysis

Results obtained from the nutritional analysis presents the average of three replicates, determinations expressed ± as mean and standard deviation (S.D). All the data obtained were statistically analyzed using IBM Corp. Released 20 20. IBM SPSS statistics for windows version 27.0 Armonk, NY: IBM Corp. Significant difference among the various treatments were evaluated through multivariate analysis of variance (ANOVA), and Duncan multiple comparison post hoc tests were used to separate the means where differences existed ($p \leq 0.05$).

6.2.10 Ethical clearance

The ethical clearance for this study was obtained from the Research Ethics Committee at the University of KwaZulu-Natal with Reference number **HSSREC/00000435/2019**. Consent form was used to obtain key informants' and panelist willingness to participate in the study.

6.2.11 Sensory evaluation exercise

A total of N=60 untrained panelists who are regular consumers of *Ujeqe* were recruited to assess the consumer acceptability level of the ALP-supplemented *Ujeqe* prototypes against the control sample(Curtis, 2013, Qumbisa et al., 2021). The panelists for the sensory evaluation were chosen because they are regular consumers of *Ujeqe* (steamed bread) and are familiar with and tasted *Amaranthus* food products. The consent of the panelist was obtained using informed consent form before the sensory evaluation. *Ujeqe* prototypes were served on a ceramic saucer, and each panelist evaluated four samples comprised of (0%, 2%, 4%, and 6%). Sensory attributes were assessed on a scale of five-point hedonic scale of pictorial smiling faces, where parameters include (dislike very much, dislike slightly, neither liked nor disliked, like slightly, and like very much) were rated for the sensory attributes and the overall consumer acceptability level. Panelists were instructed on the right way of filling the scorecard, which evaluates the colour, taste, Aroma, texture, and overall acceptability. To avoid any biasness, samples were assigned a unique three-digit code; Samples were served in a randomized order obtained from a table of random permutations of nine. Also, serviette and a cup of mineral water (aQuelle still water) was provided on the Table of each panelist. Panelists were instructed to rinse their mouths before tasting the first sample of *Ujeqe* and, after the testing each of the four *Ujeqe* prototypes. This was done to avoid interference with previous taste of any food samples. serviette was provided on the Table of each panelist. Results obtained from all parameters were then statistically analyzed. All analysis was carried out in triplicate and the data was reported as means ± and standard deviation and significant difference among treatments was evaluated through analysis of variance (ANOVA)

6.3 Results and Discussion:

6.3.1 Indigenous knowledge and perception of *Ujeqe* in the study area

Ujeqe is perceived as a type of traditional bread made by steaming, contrary to the conventional baked white bread consumed worldwide (Huang and Miskelly, 2016). All groups, excluding babies in the study area, eat *Ujeqe*. *Ujeqe* is a traditional food that is well-appreciated because the ingredient is easily accessible and easy to prepare. In the study site, *Ujeqe* is consumed at any time of the day, either as a meal or snack. Furthermore, *Ujeqe* is a traditional foods of the Zulus that is, strategic and exceptional food, often served in several conventional events: including weddings and funerals, as well as in cultural and religious ceremonies, especially during ancestral worship (Modi, 2009, Moulton, 2016). Considering the indigenous knowledge system (IKS) perspective, *Ujeqe* has been made from composite flour of mealy maize. However, it is now often made from ingredients such as plain wheat flour (PWF), sugar, salt, and oil or margarine, of which proportions are estimated based on the number of people to be served in the household. Those financially buoyant include ingredients like carrots and milk in their *Ujeqe* recipe. Although a blend of plain wheat flour and maize flour is believed to make the *Ujeqe* denser and more filling food for those engaged in strenuous activities. The community members appreciate traditional foods; however, the regular consumption of *Ujeqe* void of nutrient-dense food sources like fruits and vegetables is considered food that is only high in energy but limited essential nutrient. Such food can only address the quantity of food which only caters for the food security of the people and not-nutrition the security that considers the adequacy and of the quality of food(Qumbisa et al., 2021). Food that provides nutrition security is diversified in composition such that it optimizes the inadequacies of an essential nutrient in staple foods, including *Ujeqe*(Modi, 2009, Achigan-Dako et al., 2014, Moulton, 2016, Qumbisa et al., 2021)

6.3.2 Macronutrient composition of the raw materials for *Ujeqe*

Macronutrients are foods nutrient that is needed in larger quantities to optimize wellbeing. Macronutrients include carbohydrates, fats, and protein, the essential component of the daily diet that supplies energy to humans. The other macronutrients include the food's fibre, Ash, and moisture content. Micronutrients are food nutrients that are essential for wellbeing but are needed in small quantities (Saravia et al., 2021). The selected macronutrient and mineral content of the raw materials for *Ujeqe* plain wheat flour (PWF) and *Amaranthus* leaf powder ALP) were analysed. The results are presented in Tables 6.2 and 6.3.

Table 6.2: Macronutrient composition of wheat flour and *Amaranthus* leaf powder

(Macronutrient g/100 g dry matter) basis)	**PWF**	**ALP**
Carbohydrate	74.03 ± 2.21^{a}	41.6 ± 0.61^{b}
Moisture	10.06 ± 0.08^{a}	4.41 ± 0.34^{b}
Ash	2.37 ± 0.12^{a}	17.97 ± 0.11^{b}
Fat	1.58 ± 0.14^{a}	4.47 ± 1.32^{b}
Protein	11.96 ± 2.31^{a}	31.56 ± 1.76^{b}

[1] Mean values ±SD with the different superscripts across the row are significantly ($p \leq 0.05$) different.
[2.] PWF means plain wheat flour, and ALP means *Amaranthus* leaf powder

Table 6.2. describes the macronutrient composition of plain wheat flour (PWF) and *Amaranthus* leaf powder (ALP) as the active raw materials that was used to develop *Ujeqe* in this study. The ALP's Ash, fat, and crude protein content were significantly ($p < 0.05$) higher than the content in PWF. Although *Amaranthus* is a neglected food crop, the proximate content suggests it as a promising a promising supplement for cereal-based food product, including *Ujeqe.*

The moisture content of both raw materials ranged (4.41%) (10.06%) The study are similar to trend reported in previous studies (Kushwaha et al., 2014, Junejo et al., 2021). The low moisture content of the plain wheat flour and *Amaranthus* leaf powder are adequate which implies the keeping self-life of the raw materials before it was used for *Ujeqe* production. *Amaranthus* being a fresh produce is a highly perishable thus either fresh or powdered must be well preserved to avoid spoilage and post-harvest losses (Emmanuel and Babalola, 2022). Thus, it is identified that *Amaranthus* processing and preservation must be adequate to prevent quantity and nutrient losses so that it can be available mainly in the lean seasons and at a compensable price (Medina et al., 2012, Khatoniar and Barooah, 2018). Since the moisture of raw materials were low, it implies that high moisture content in the ALP and PWF connotes susceptibility to spoilage, which may lead to the introduction of contaminants in new food products that may lead to the low shelf life of the food product. It is identified that the lower moisture content in cereal flours and leafy greens shows that it was well-processed, stored food products (Odunlade et al., 2017, Junejo et al., 2021).

Carbohydrate content in this study ranged from (41.6% to 74.03%), and the carbohydrate observed in ALP was significantly ($p < 0.05$) lower compared to that of PWF. It confirms that cereals, including wheat, are higher in carbohydrates than leafy vegetable food materials, like *Amaranthus.* Thus, the sole consumption of starchy staple foods, including plain wheat-based food products like *Ujeqe* can result in a high intake of high calories with limited micronutrient intake(Jaworski et al., 2015). Hence staple foods including cereal foods must be enhanced with nutrient-dense food for optimum nutrition security. The ALP was low in carbohydrates, showing that *Amaranthus* leaves can complement staple foods; hence, *Amaranthus* can be utilized to prepare nutritious *Ujeqe* with a low glycaemic index.

This study also demonstrates that *Amaranthus* can be consumed in a quantity that can supply some amount of energy besides its essential nutrient endowment. *Amaranthus* can be an excellent complementary food for cereal-based food products, including wheat-based products like *Ujeqe.* Moreover, *Amaranthus* can be an option of food for a reduced gluten diet, especially for those who are gluten-sensitive or intolerant (Achigan-Dako et al., 2014, Ramdwar et al., 2017). Also, the low content of carbohydrates in this study hypothesis that *Amaranthus* leaves is an excellent food for those on a low-carb diet or those that desire to lose weight(Lawal et al., 2022). (Kaur et al., 2010, Bhat et al., 2015, Kamotho et al., 2017). The ALP composite flour food products could benefit those with gluten-intolerant problems but also those with casein health challenges/allergies(Singh et al., 2019, Junejo et al., 2021). The high Ash content observed in ALP compared to PWF suggests there is an appreciable amount of minerals in *Amaranthus* leaves powder, which can impact positively on the nutritional content of the supplemented food products. Table. 2. shows that the ash content was higher in ALP than in PWF. A high ash content in food materials, including *Amaranthus* leafy green, connotes their richness in mineral content. This means that ALP is an excellent source of minerals that can optimize the inadequacies of mineral deficiencies in staple foods.

Similarly, the fat content in this study was higher in ALP than in PWF. The fat in *Amaranthus* has been identified as trace fats that is free from cholesterol. The high-fat content of the ALP suggests that a blend of any cereal-based foods with ALP would distinctively lead to an enhanced fat content of cereal foods limited in fat. Consequently, *Amaranthus'* trace fat content will also lead to the palatability of food products and improved nutrition security (Sclafani and Ackroff, 2012, Berthoud et al., 2021). (Odunlade et al., 2017). Likewise, the protein content presented in Table 6.2. of this study was equally higher in ALP than in PWF, with a statistically significant difference at $p < 0.05$. This study is consistent with a previous study conducted by Famuwagun, (2017) (Odunlade et al., 2017). which states that there is high protein content in dried vegetable powders which is evident in ALP; hence, (Odunlade et al., 2017).

Table 6-3: The mineral content of wheat flour and *Amaranthus* leaf powder

(mg/100 g dry matter basis)	**(PWF)**	**(ALP)**
Calcium	30.00 ± 0.00[a]	2600.00 ± 0.03[b]
Magnesium	40.00 ± 0.00[a]	1210.00 ± 0.01[b]
Potassium	5400.00 ± 0.11[a]	160.00 ± 0.1[b]
Sodium	60.00 ± 0.01[a]	130.00 ± 0.01[b]
K/Ca+ Mg	0.11 ± 0.00[a]	0.05 ± 0.00[b]
Phosphorus	0.02± 0.00[a]	0.06 ± 0.01[b]
Zinc	3.27 ± 0.58[a]	7.07 ± 0.58[b]
Manganese	1.434 ± 0.58[a]	3.00 ± 0.00[b]
Copper	1.00 ± 0.00[a]	1.73 ± 0.58[b]
Iron	7.20 ± 3.61[a]	24.00 ± 16.83[b]

[1]Mean values ±SD with the different superscripts across the row are significantly different at p<0.05.
[2.] PWF means plain wheat flour, and ALP means *Amaranthus* leaf powder

Table 6.3. presents the micronutrient composition of (PWF and ALP). Besides potassium, a higher micronutrient content was observed across all the ALP nutritional profile compared to the content in PWF, and the differences recorded were statistically significant at $p<0.05$. For example, Calcium content raged between (30.00 - 260.00). Calcium is an essential mineral required for developing strong teeth and bones. It is a vital need in children, lactating and pregnant women(Dhakar et al., 2011) (The study shows that incorporating ALP in staple foods, including wheat-based *Ujeqe* food products and other calcium-deficient foods, may enhance the calcium status of the final food products.

Similarly, magnesium content ranged from (40.00-110.00). The which was higher in ALP than in PWF. The study implies that consuming food with ALP as an active ingredient would enhance the magnesium inadequacies of Magnesium in cereal-based foods. Table .3. shows that magnesium is one of the components of *Amaranthus* , consistent with previous studies (Chasapis et al., 2020). ALP had a higher magnesium content with a statistically significant difference at $p<0.05$. Green leafy vegetables are excellent sources of magnesium. Magnesium is found throughout the human body; it boosts human performance, combats depression, supports healthy blood sugar levels, and promotes a healthy heart. It has anti-inflammatory benefits that may help prevent migraine attacks and improve Premenstrual syndrome. Also, the copper content of the supplemented prototype is described in Table. 3. ranges from 1.00 -1.73. The sodium content of the raw material in Table 6.3, is reckoned within the range when compared with the recommended dietary intake for adults (0.02–1.4%) recommended per day, hence, sodium is within the acceptable limits (Punchay et al., 2020). Low sodium contents in vegetables, including indigenous vegetables like *Amaranthus* , have also been reported in previous studies (Nkafamiya et al., 2010).

The iron content in Table 6.3 ranged from (7.20 –24.00). The study shows that ALP had a higher iron composition, implying that *Amaranthus* leaves are a rich source of iron; therefore, it can be explored as a supplement in cereal-based foods, like *Ujeqe.* Iron-rich foods are fundamental in human nutrition because they have been investigated to play a vital role in the functioning of the human system. For example, iron is essential for transporting oxygen from respiratory organs to other body parts (Abbaspour et al., 2014). Iron also prevents anaemia, low blood pressure and helps maintain and keep an individual energetic for everyday activities. It is argued that all the essential nutrients in the diet play a crucial role in maintaining an "optimal" immune response. However, insufficient, and excessive intakes can negatively affect the immune status and may render one susceptible to various pathogens. The zinc composition of ALP and PWF ranged from (3.267-7.067); this implies that consumption of ALP food products can provide the consumer with Zinc.

Most of the selected minerals analysed in this study are all essential for well-being. All minerals were observed to be higher in ALP composition than PWF; this study suggests that the incorporation of ALP in any staple food may enhance the essential micronutrient inadequacy issues in cereal-based food products, including *Ujeqe* (N et al., 2021). *Amaranthus* is suggested as an excellent complement in wheat-based food products, including *Ujeqe.*

Table.3. shows that zinc was high in ALP than in PWF. This is because zinc is an essential mineral that is needed for the proper functioning of the human system. Although it is considered a trace element, it is vital for human health(Chasapis et al., 2020). It plays a fundamental role in the metabolic processes, while boosting human immunity against diseases and supports the functioning of many biological processes (Grüngreiff et al., 2020). Low zinc content and ion bioavailability have been linked with limited monoresistance to infections, even during aging (Ferenčík and Ebringer, 2003). The effects of zinc on human health are based on the zinc ion's intra- and extracellular regulatory function and its interactions with the proteins. Deficiency of zinc has been linked with impaired metabolic processes, reduced resistance to infections resulting from a poor immune function that may change the skin and its appendages, and disorders of wound healing and haemostasis (Grüngreiff et al., 2020, Chasapis et al., 2020). About 17% of the globe suffers from zinc deficiency. The deficiency of zinc has been known to affect many organ systems and can lead to the dysfunction of many humoral and cell-mediated immunity, thus increasing the susceptibility to infections(Chasapis et al., 2020).

(Emmanuel and Babalola, 2022) This study also presents a higher Copper content in ALP than in PWF. Copper is an essential element for wellbeing; however, it is required in little amount by the human body but is beneficial as it helps enzymes the transfer energy into the various human cells of the body(Putriani et al., 2022).

The manganese content in this study ranged from 1.434-3.00, and ALP had the highest composition compared to PWF. Manganese is a trace mineral that all humans need in small amounts(Putriani et al., 2022). However, it is required for the normal functioning of the brain, nervous system, and body's enzyme systems. Manganese can be found in seeds and whole grains, as well as in smaller amounts in legumes, beans, nuts, and leafy green vegetables, including *Amaranthus* (Putriani et al., 2022). This implies that a diversified diet is key to adequate nutrition for humans' optimum wellbeing. Furthermore, manganese helps the human body utilize several vitamins, including choline, thiamine, and vitamins C and E, ensuring proper liver function. Additionally, it works as a cofactor, or helper, in development, reproduction, energy production, immune response, and the regulation of brain activity(Putriani et al., 2022).

6.3.3 Effects of ALP supplementation on *Ujeqe* macronutrient composition

Ujeqe is a cereal-based traditional food that is appreciated as a meal and sometimes as a snack in the rural community of Empangeni, South Africa. Since it is a starch-based staple food, it has been identified that monotonous consumption of staple foods, including that of *Ujeqe* is considered the top contributing cause of micronutrient deficiency challenges across developing countries. Supplementation of cereal-based food has been explored using nutrient-dense materials like moringa *oleifera* leaf powder and *Amaranthus* leaf extract, showing that the food supplements were enhanced nutritionally. The grains of *Amaranthus* have also been utilized to improve staple food's nutritional contents. However, the effects of *Amaranthus* leaf powder supplementation, especially on *Ujeqe* macronutrients, have not been explored(Chasapis et al., 2020).

The incorporation of the common *Amaranthus dubius* in the study area enhanced the nutrient content of the supplemented *Ujeqe* thus Table 6.4-6.5 describes the impact of ALP on both macronutrient and micronutrient composition of the ALP 2%, 4% and 6% supplemented *Ujeqe* prototype.

Table 6-4: Macronutrient composition of ALP-supplemented *Ujeqe* prototypes

	(ALP %)			
(g/100 g dry matter basis)	**0**	**2**	**4**	**6**
Carbohydrate	73.21 ± 0.25^{b}	71.09 ± 0.45^{a}	70.32 ± 0.31^{a}	70.26 ± 0.56^{a}
Moisture	7.49 ± 0.14^{a}	8.03 ± 0.03^{d}	7.67 ± 0.05^{b}	7.85 ± 0.1^{c}
Ash	1.39 ± 0.03^{a}	2.2 ± 0.01^{c}	2.05 ± 0.01^{b}	2.31 ± 0.03^{d}
Fat	4.62 ± 0.13^{b}	3.39 ± 0.15^{a}	4.4 ± 0.42^{b}	4.96 ± 0.49^{b}
Protein	13.33 ± 0.02^{a}	15.27 ± 0.33^{b}	15.56 ± 0.65^{b}	14.64 ± 0.5^{b}
Energy (Kcal)	387.58 ± 0.48^{b}	376.04 ± 0.87^{a}	381.08 ± 3.87^{ab}	380.15 ± 2.61^{a}

[1]Mean values ±SD with the different superscripts across the row are significantly different at $p<0.05$.
[2.] ALP means *Amaranthus* leaf powder.

Table 6.4. describes the macronutrient content of the ALP 0%, 2%, 4%, and 6% supplemented *Ujeqe* prototypes. The increased concentration of ALP resulted in a reduced carbohydrate content across all the *Ujeqe* supplemented prototypes but are not statistically significant. A similar decrease in carbohydrates has been reported in a study conducted by(Odunlade et al., 2017) .Therefore the reduction of carbohydrates across supplemented food samples may be attributed to low glycaemic index in leafy vegetables including *Amaranthus* which has shown that the carbohydrate content in ALP was low. Thus, staple foods containing ALP may have low carbohydrates, which can be an option for those on a low-carb diet. However, the increased ALP in the supplemented prototypes resulted in increased Ash content of the *Ujeqe* food prototype, which ranged between 1.39%-2.31%. A higher effect of the increased ALP substitution was statistically different at $p<0.05$. It was observed in Table 4 that the ash content of 2%, 4%, and 6% ALP *Ujeqe* supplemented prototypes were high. This study, therefore,

implies that an increased concentration of ALP in staple foods, including *Ujeqe* enriches the mineral contents of the supplemented prototypes compared to the control sample. This is in agreement with studies that report that foods containing leafy vegetables often have higher ash contents which connote a mineral-rich food product (Beswa et al., 2016, Bolarinwa et al., 2019). Table 6.4 describe the fat content of the ALP-supplemented *Ujeqe* prototype: (4.62%-4.96%). Although higher content of fat was reported in 6% substitution of ALP, it was not statistically significant with the control sample and the 4% it has been reported that leafy vegetables, including ALP, are low in carbohydrates and fats (Achigan-Dako et al., 2014, Aderibigbe et al., 2022). However, the presence of fats in foods enhances the palatability of the food products. Vegetables, including *Amaranthus* fats, are considered healthy fats because they are considered as (unsaturated fat) which include monounsaturated fat and polyunsaturated fat. It has been reported that fats enhance food taste(Odunlade et al., 2017). It has been reported that green leafy vegetables are sources of essential omega fatty acids, which are exceptionally high in omega-3 compared to omega-6 fatty acids. The presence of these fats in food enhances the palatability and nutritional content of the food products(Odunlade et al., 2017) . Since, the fat content of the control sample and the ALP-supplemented *Ujeqe* prototype 4 and 4% and 6%was not statistically significant compared to the control, then those desiring to gain weight may need other sources of healthy fats included in their *Amaranthus* food products to optimize human dietary needs.

Similarly, the protein content of the supplemented prototypes in Table 6.4. ranged between 13.33%-15.56%. A higher increase was recorded in the protein content of the 2% compared with control sample similarly there an increase was recorded in 4% ALP-supplemented *Ujeqe* prototypes compared to the control sample and 2% sample. Even though, there by chance, there is a drop in 6%. However, the 4% and 6% samples thus this study demonstrate that a higher substitution of ALP in staple foods can enrich the protein content of any staple-supplemented foods products. Table 6.4. shows that the increased concentration of ALP in *Ujeqe* enhanced the nutritional content of supplemented prototype compared to the control prototype *Ujeqe.* The protein content was observed to be higher in the sample with 2% and 4% ALP substitution. However, since the data in 2% and 4% results suggest that the ALP substitution ratios 4 and 6% are not statistically significant. Thus, 2% and 4% in this study, ALP are adequate for improving the macronutrient content of *Ujeqe.* This study indicates that *Amaranthus* has nutrient-enriching effects on the nutritional composition of the conventional *Ujeqe* and may also enhance similar cereal-based foods with inadequate essential nutrients. Studies around the utilization of *Amaranthus* grains and fortification have been investigated in several studies(Achigan-Dako et al., 2014). However, Investigations of ALP in staple foods are scarce/limited. It is essential to note that the information on the application of ALP in *Ujeqe* is scarcely reported; thus, the study appears to be the first to write on the nutrient profile of (0%, 2%, 4%, and 6%) ALP-supplemented *Ujeqe* food products.

6.3.4 Effects of ALP Supplementation on *Ujeqe* micronutrient composition

The effects of legumes, pseudocereals, and leafy vegetables like moringa *oleifera* have been used to enhance staple foods for improved food and nutrition security and the alleviation of malnutrition(Puspasari et al., 2020, Alekhina et al., 2021). Hence this study explores the effects of ALP on the micronutrient content of ALP-supplemented *Ujeqe* for improved food and nutrition security.

Table 6-5: The mineral content of ALP-supplemented *Ujeqe*

	(ALP %)			
(mg/100g dry matter basis)	**0**	**2**	**4**	**6**
Calcium	30.00± 0.00[a]	70.00 ± 0.00[b]	120.00 ± 0.01[c]	140.00 ± 0.01[d]
Magnesium	120.00± 0.12[a]	50.00 ± 0.01[a]	1 0.00 ± 0.00[a]	80.00 ± 0.04[a]
Potassium	210.00 ± 0.00[a]	280.00 ± 0.01[b]	370.00 ± 0.01[c]	430.00 ± 0.02[d]
Sodium	290.00 ± 0.00[a]	520.00 ± 0.00[c]	300.00 ± 0.00[a]	360.00 ± 0.06[b]
K/Ca+Mg	0.07 ± 0.42[a]	0.08 ± 0.02[a]	0.07 ± 0.02[a]	0.08 ± 0.20[a]
Phosphorus	0.01 ± 0.00[a]	0.03± 0.07[b]	0.02± 0.00[a]	0.02 ± 0.20[a]
Zinc	3.27 ± 2.08[a]	3.20 ± 0.00[a]	3.3 7± 0.58[a]	3.47 ± 3.06[a]
Manganese	0.80 ± 0.00[a]	0.90 ± 0.00[a]	1.00 ± 0.00[a]	1.00± 2.65[a]
Copper	0.17 ± 0.58[a]	0.17 ± 0.57[a]	0.30± 0.00[b]	0.2 7 ± 0.58[ab]
Iron	5.17 ± 7.40[a]	5.27 ± 2.08[a]	6.13 ± 2.31[b]	6.50 ± 14.18[c]

[1]Mean values ±SD with the different superscripts across the row are significantly different at $p<0.05$.
[2]*Amaranthus* leaf powder (ALP)

Table 6.5. shows that the micronutrient content of ALP-supplemented *Ujeqe* prototypes were enhanced with statistically significant $p<0.05$. The increase was evident in the following selected minerals, including calcium, potassium, phosphorus, copper, and iron. It has been reported that *Amaranthus* leaves are dense in essential nutrients, including vitamins and minerals(Alegbejo, 2013). This study indicates that the increased ALP ratios of ALP in the supplemented prototype resulted in an enhanced *Ujeqe* food product; the enhancement was notable in some highlighted minerals, which are statistically significant $p<0.05$. It has been

identified that both quality and quantity must be considered in meal preparation and consumption. Therefore, to optimize wellbeing, ALP inclusion into other staple food cannot be overemphasized as this is confirmed to enrich the nutrient content of the staple food products. *Amaranthus* spinous vegetable variety, including *Amaranthus dubius* has been reported to have higher nutritional content than other Amaranths species. The ALP-supplemented prototypes were enhanced compared to the control sample; however, not all prototypes were statistically significant. It has been noted that food processing methods such as thermal treatment on leafy vegetables, including *Amaranthus,* can harm their nutritional content. Most of the heat-sensitive nutrients can be lost or destroyed during food formulation. (Olusanya, 2018, Putriani et al., 2022). This implied that the nutritional value of *Ujeqe* is dependent not only on the type of species/ingredients used but, also on the method of food processing technique and the heat treatment employed. Therefore, the processing of leafy vegetables including *Amaranthus* should be done under controlled temperature to minimize nutrient loss.

Table 6-6: Sensory evaluation and consumer acceptability of ALP-supplemented *Ujeqe*

	ALP composition (%)			
Sample	**0**	**2**	**4**	**6**
Colour	3.00 ± 0.00^{a}	3.00 ± 0.00^{a}	3.00 ± 0.00^{a}	3.00 ± 0.00^{a}
Aroma	4.55 ± 0.7^{abc}	4.12 ± 0.87^{ad}	3.9 ± 0.84^{bc}	3.44 ± 1.1^{cde}
Taste	4.00 ± 0.00^{a}	4.00 ± 0.00^{a}	4.00 ± 0.00^{a}	4.00 ± 0.00^{a}
Texture	4.90 ± 0.31^{abc}	4.52 ± 0.63^{ad}	4.24 ± 0.86^{be}	3.59 ± 1.14^{cde}
Overall Acceptability	4.82 ± 0.4^{ab}	4.49 ± 0.71^{c}	4.24 ± 0.88^{ad}	3.59 ± 1.13^{cd}

[1]Mean values ±SD with the different superscripts across the row are significantly different at p<0.05.
[2]*Amaranthus* leaf powder (ALP)

6.3.5 Sensory evaluation and consumer acceptability of ALP-supplemented *Ujeqe*

Table 6.6 describes the mean and ± standard deviation score for the sensory attributes and. the consumer's overall acceptability of the ALP-supplemented *Ujeqe* prototypes. The colour and taste of the ALP-supplemented prototypes were not statistically significant (p>0.05), hence it did not affect the panellists acceptance of the supplemented samples. The acceptance level of the prototype samples could be because healthy eating is trending worldwide even in South Africa and people are becoming more health conscious, thus the incorporation of *Amaranthus* in staple food like *Ujeqe* was well appreciated among the panellists. Similarly, people in the study area are familiar with the consumption of *Amaranthus* in it various forms so it colour and taste had no negative influence on their acceptance the *Ujeqe* prototypes formulated. This study shows that the control, 0% *Ujeqe* sample from plain wheat flour was highly acceptable by the panellists compared to the three treatments containing ALP at different concentrations (2%, 4%, and 6%). The study further shows that 2% prototype was the most acceptable sample compared to the control sample (0%). However, there was no statistically significant difference between prototype 4% and 6% ALP substitutions. Although Aroma, texture and consumer acceptability were statistically significant at p<0.05. These results are similar to those reported in previous study (Olusanya, 2018, Qumbisa et al., 2020), where leafy vegetables were used in developing staple food products. *Amaranthus* leaves and their succulent stems are cheap and available. They have been investigated as excellent protein sources with essential amino acids lysine and methionine, carotenoids, ascorbic acid, dietary fibre, and essential minerals, such as calcium, magnesium, potassium, phosphorus, iron, zinc, copper, and manganese (Peter and Gandhi, 2017, PharmEasy, 2021). In this study, some species of the spinous variety, especially the *Amaranthus dubius* variety, have been recorded as nutrient-dense [22]. It has been widely used in traditional medicine as a medicinal plant to remedy malarial, diabetic, bacterial, and viral diseases, helminthic infections, and as a snake antidote (Achigan-Dako et al., 2014, Ramdwar et al., 2017, Aderibigbe et al., 2022). *Amaranthus dubius* leaf powder is an excellent sustainable food plant that can be explored in various staple food products for improved food and nutrition security; and addressing micronutrient deficiencies challenges especially among the malnourished population.

Table 6-7: Physical properties of *Ujeqe* alp-supplemented samples

Samples Ratio	Mean-loaf weight± SD (g)	Mean-loaf length± SD (cm)	Mean-loaf breadth± SD (cm)	Mean. loaf height± SD (cm)	Mean-loaf volume ± SD (cm^3)	Mean Specific loaf volume± SD (cm^3/g)
0%	164.83±6.75[a]	7.52±0.76[a]	6.50±0.00[a]	8.15±0.56[a]	398.02±23.98[a]	2.41 ±0.70[a]
2%ALP	164.73±5.22[a]	7.77±0.25[b]	6.23±0.58[a]	9.00±0.00[ab]	435.72±15.06[a]	2.64±0.02[ab]
4%ALP	171.80±8.66[a]	8.00±0.00[b]	6.43±0.81[a]	8.73±1.15[ab]	454.45±11.84[a]	2.63±0.53[ab]
6%ALP	173.87±9.50[a]	8.00±0.00[b]	6.80±0.35[a]	9.48±0.29[b]	515.86±25.56[a]	2.97 ±0.12[b]

[1]Mean ± SD; Values with the same superscript across the columns are not statistically significantly different (P<0.05)

6.3.6 Effect of *Amaranthus* Leaf Powder on the Physical Properties of the *Ujeqe* Samples

Table 6.7 shows the physical properties of *Ujeqe* produced from composite flours of wheat and *Amaranthus* leaf powder in varying percentage (0%, 2%, 4% and 6%). Although there was increase in the loaf volume of *Ujeqe*, however, there was no statistical significance difference across the loaf volume of the ALP supplement *Ujeqe* prototypes. Similarly, there was increase in the specific volume. However, the specific loaf volume of the supplemented *Ujeqe* increased significantly *($p<0.05$)*. This study from 173.70 to 164.73 cm3 and 2.97 to 2.94 cm3 /g respectively. This loaf volume and specific volume increased in volume in a progressive manner, but the increase is not thing, the reduction of the gluten in the wheat after ALP substitution could not decrease the specific volumes of all the supplemented of *Ujeqe* sample. Only the control sample (0% = 2.41 and 6%=2.97) ALP supplemented *Ujeqe* had significant increase of specific volume. On a general note, the loaf volume of the *Ujeqe* increased but significantly Perhaps this could be due to the fermentation/proofing time of the dough before. It has also been reported by other researchers that partial replacement of wheat flour with non-glutinous flour results in lower bread volumes thus the loaf and specific volume of the bread is similar the records reported by Author Sengev, (2013) (Sengev *et al.,* 2013) .Also, the weight of the *Ujeqe* did increase with substitution of ALP but the increase in the bread weight was not statistically significant. Perhaps reduction in fermentation/proofing time could not possibly reduce the *Amaranthus* Leaf Powder. It has also been reported by other researchers that partial replacement of wheat flour with non-glutinous flour results in lower bread volumes, however, increase in longer fermentation/proofing time could possibly reduce the specific volume. Dietary monotony has also been identified as acritical issue in South Africa (Mabhaudhi *et al.,* 2016) hence the need for increased use of underutilized vegetables like amaranth to expand the food basket, thereby diversifying diet.

6.4 Conclusion

Amaranthus dubius leaves were self-processed into *Amaranthus* leaf powder (ALP) under a controlled food laboratory condition. The raw materials: plain wheat flour (PWF) and ALP, were analysed in triplicate for nutritional composition. ALP had higher nutritional composition compared to plain wheat flour. The ALP ratio: (0%, 2%, 4%, and 6%) was explored in plain wheat *Ujeqe*; and supplemented *Ujeqe* prototypes were enhanced in macro-nutrient. Notably, the protein content may provide food and nutrition security for protein malnourished population. Likewise, the ash content of the ALP supplemented prototypes was enhanced, which depicts that the enriched prototypes were mineral wise enriched. Thus, the selected minerals content of the supplemented *Ujeqe* was statistically significance level at $p<0.05$. Zinc is an essential mineral that is needed to optimize wellbeing. Although the zinc content increased across the prototypes, the mean value differences were insignificant. The sensory evaluation result shows that Aroma and texture were statistically significant at $p<0.05$, implying that increased ALP substitution affected the consumer preference for texture and aroma of the prototype samples. However, increased ALP in *Ujeqe* did not affect the consumer acceptability of the colour and taste of the supplemented prototypes (Table 6). The findings of this study show that increase in ALP supplementation did not compromise the overall acceptability of *Ujeqe* prototypes. The 6% ALP *Ujeqe* was nutritionally enhanced; however, it was the least appreciated sample, but there was no statistical significance between the prototype 4% and the 6% sample. However, the 2 % ALP *Ujeqe* prototype was the most acceptable in this study compared to the reference (control) 0% sample. *Amaranthus* is one of the cheapest, nutrient-dense underutilized leafy vegetables with excellent potential to optimize the dietary needs of the malnourished population with limited resources. There is a need to disseminate information on the nutritional prospect of ALP-supplemented food products such as ALP-supplemented *Ujeqe* via workshops, seminars, or campaigns. Food-based strategies encouraging a diversified diet, such as ALP supplementation in staple foods, are tools for tackling malnutrition at the household level. Also, fibre is one of the components of leafy vegetables, including *Amaranthus;* however, the fibre content was not analysed in this study. Hence, future studies can include fibre analysis and shelf-life study of ALP *Ujeqe* samples.

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CHAPTER 7: SUMMARY AND RECOMMENDATIONS

7.1 Summary

Chapter 1 focused on the prevalence of malnutrition and the problem-statements. Chapter 2 presented the potential of underutilised indigenous vegetables leaves, and *Amaranthus* in particular, for improved food and nutrition and addressing malnutrition challenges. The underlying causes of malnutrition were identified as poverty which is a forerunner to food insecurity and nutrition insecurity issues. Moreover, the underutilisation of nutrient-dense available food materials was also highlighted as a top precursor to most preventable nutrient-related, micronutrient deficiencies challenges, especially at the household level. The review aspect of this study provides indepth information about *Amaranthus* as a multipurpose and essential nutrient-rich plant with phytochemicals and bioactive components that have great health benefits. The seeds have been utilised as enhancers of staple foods in other parts of the globe, however, the leafy vegetables aspect of *Amaranthus* has been underutilised and have never been used in *Ujeqe* a (traditional bread). An undiversified, monotonous starch-based diet has been identified as a top cause of malnutrition. The research methods (qualitative and quantitative) and methodology and conceptual framework of the study were detailed in Chapter 3. Chapter 4 presented the dynamics of *Amaranthus* along its value chain; and the most commonly sold/consumed *Amaranthus* species in the study area were identified. Chapter 5 assessed the utilisation of *Ujeqe* along with the perceptions and patterns of *Amaranthus* leaves consumption for improved food and nutrition security and nutrient intake of *Ujeqe*. In this study, *Ujeqe* was identified as a cereal-based food that could be used as a vehicle for a nutrient-dense complementary food such as *Amaranthus* leaves to optimise the nutrient inadequacies in wheat-based foods products. The complementary foods for *Ujeqe* in the study site were identified including legumes and those of the animal origin however, not all people in the rural community are able to access them at all times; and the consumption of *Ujeqe* as a single meal without nutrient rich foods like the vegetables, fruits or other sources of essential nutrient is considered an inadequate diet which can expose regular consumers to the risk of malnutrition, including the deficiencies of micronutrient malnutrition called “hidden hunger”. To address the SDGs goals and improve food and nutrition security status of people, this study is an intervention measure that seeks to address malnutrition at the household level, using available nutrient-dense food sources to optimise the nutrient inadequacies in staple foods. Since *Amaranthus* is an underutilised but nutrient-dense indigenous plant, an investigation into the nutritional potentials of Amaranthus and consumer acceptability of *Amaranthus* leaf powder supplemented *Ujeqe* for improved food and nutrition security of South African rural communities was explored. The findings are presented in Chapter 6. The findings showed that the increased concentration of ALP resulted in a nutrient rich *Ujeqe* which was evident in the protein and selected mineral content. The sensory evaluation exercise indicated that all samples were acceptable. The 6% ALP *Ujeqe* prototype was the most enriched, but the 2% sample was the most acceptable enriched *Ujeqe* compared to the control sample followed by 4% and 6% respectively. There was no statistically significant difference in the overall consumer acceptability level of the enriched sample when compared with 0%, 2% and 4% ALP supplemented *Ujeqe* prototypes. Conclusively, ALP supplemented Ujeqe was enhanced both in macro and micronutrients. The high ash content recorded connotes that the ALP supplemented samples were rich in minerals. Since the mineral content of the raw material of ALP was significantly higher than PWF, the supplemented *Ujeqe* with ALP 6% was observed to contain the highest mineral content. Hence, from the nutritional point of view the formulation is significant and can be used to address nutrient deficiency challenges. By implication, ALP supplementation in staple foods can be a potential food-based approach that is cost-effective and a sustainable measure for addressing food and nutrition insecurity among the malnourished population. The fibre in this study was not analysed; therefore, future studies can explore ALP supplemented *Ujeqe*'s fibre content and microbial tests can be carried out to determine its shelf-life stability. There is a need for dedicated and continuous efforts in research on underutilised food plants including *Amaranthus* for the purposes of food and nutrition security. Also, effective implementation of relevant research that can help in the domestication of *Amaranthus* cannot be overemphasised. Similarly, improving the small-scale farming of *Amaranthus* to a larger scale appears to be a realistic way forward. However, the South African government should assist small-scale farmers of *Amaranthus* with all the extension services as this may enhance their productivity and provide food and nutrition security for the community. Policymakers should consider the provision of land, finance, fertiliser, seed, herbicides, fence, insecticide, and grants to encourage farmers to plant vegetable foods like *Amaranthus*. Enhancing small-scale farmer capital should involve financial support from the government and the provision of land.

7.2 Contribution of the study

In Objective 2, focusing on the underutilisation versus nutritional-nutraceutical potential of the *Amaranthus* food plant, it was established that even though *Amaranthus* is available across the globe (America, Asia, and Africa), its use is limited. Literature was reviewed and it was noted that it is nutritionally endowed with great potential to optimise staple foods; however, food and nutrition insecurity still exists in many developing countries, including South Africa. Food and nutrition security continue to be a big challenge especially at the household-level of the rural population. This is because household access to safe and nutritious food suitable for dietary needs of the marginalised, is compromised by consumer selection of cheap and starchy-based foods that are loaded with sugar. The most vulnerable people are being exposed to hunger and missing meals, with many going to bed hungry. Thus, monotony of starch and cereal-based foods with low consumption of vegetables and foods, especially leafy green vegetables, is identified as a critical issue that contributes to the malnutrition in many rural communities of the developing countries including South Africa. This review, thus, suggests the need for increased use, and consumption of vegetables, especially the underutilised leafy vegetables. *Amaranthus* should be included in the food basket system for a sustainable diversified diet at the household level. In other words, the inability to diversify diet with leafy greens often results in malnutrition of all kinds including micronutrient nutrient deficiencies (also known as hidden hunger) which impacts negatively on the most vulnerable. The review noted that a*Amaranthus* seeds have been utilised in the development of nutrient-rich foods, but the leaves have been underutilised especially in staple foods like *Ujeqe.*

Chapter 4 of this study, titled "Dynamics of the *Amaranthus* in urban and rural value chain in KwaZulu-Natal province, South Africa", addresses Objective 2 regarding where various species (varieties) of *Amaranthus* are commonly sold and the associated value chain. Chapter 4 describes the dynamics of *Amaranthus* in urban and rural value chains in the KwaZulu-Natal province of South Africa. During this study, edible Amaranthus identified were *A. thunbergii,* A. *spinosus, A. hybridus, A. deflexus, A. hypochondriacus, A. greazicans, A. viridu, A caudatus, A. dubius, A. curuentus,* and *A. tricolour*. All these varieties are cultivated in South Africa, mainly in provinces like Limpopo, Eastern Cape, and KwaZulu-Natal. The blacks and Indians are the most common consumers of *Amaranthus* in South Africa. The value chain of *Amaranthus* described in Figure 4-1 include (1) smallholder farmers selling directly to consumers; (2) smallholder farmers selling to retailers, and (3) smallholder farmers selling directly to go betweens (collectors). The value of *Amaranthus* can be compared with other indigenous plants because they can be accessed. Exotic vegetables as seen in the retail stores are not as accessible as *Amaranthus* which can be bought directly from smallholder farmers at a cheaper rate. Chapter 5 of the study titled "Utilisation of *Ujeqe* (steamed bread) and

Amaranthus leaves for improved food and nutrition security of rural communities in South Africa" captured Objective 3 which assessed and reported on the practices and utilisation level of *Ujeqe* and *Amaranthus* for improved nutrition security.

Chapter 6 focused on the mineral composition and consumer acceptability of *Amaranthus* leaf powder supplemented *Ujeqe* for improved nutrition security. *Amaranthus dubius* was used to develop ALP supplemented *Ujeqe*. This study contributes to the body of knowledge by using a food-based approach to develop a novel nutrient-rich food, namely, ALP supplemented *Ujeqe* enhanced with protein, and micronutrients, namely calcium, potassium, zinc, copper, and iron which is considered as a cost effective, results-oriented, and sustainable measure for solving food and nutrition insecurity problems and malnutrition problems at the household-level for improved food, and nutrition security of the malnourished population. This study is the first to develop and report on the mineral profile of ALP-supplemented *Ujeqe* bread for improved food and nutrition security. Furthermore, Chapter 6 provided information on the consumer acceptability level of 2%, 4% and 6% ALP supplemented *Ujeqe.*

Amaranthus competes with spinach but because of the numerous misperceptions of the *Amaranthus* spinach is preferred because *Amaranthus* is seen as a common weed that is harvested in the wild and not widely available in malls, and is used to feed animals, hence its worth is relegated. *Amaranthus* is considered as food for the marginalised. *Amaranthus* deserves to gain recognition through increased the awareness of its nutritional potential and using it to enrich staple foods which can promote its consumption. However, more research is needed on its use in the food industry and more support is needed to increase cultivation. *Amaranthus* should be included in the range of goods sold in the malls which will increase its worth.

Amaranthus enriched *Ujeqe* was improved in the following macronutrients, namely ash and protein, and selected micronutrients, namely calcium, potassium, zinc, copper, and iron. This study found that the higher the concentration of ALP the less the consumer acceptability. All the supplemented prototypes were accepted; however, the 2% sample was the most acceptable compared with the conventional *Ujeqe*. For *Amaranthus* to be formalised in retail; novel ways of applying it should be explored in staple foods in the same way that it has been explored in *Ujeqe.*

7.3 Recommendations

1. Suitable production systems, innovative processing, and novel value-adding techniques that may promote the utilisation of *Amaranthus* are lacking. Hence it can be the focus of the food industry and individual households.
2. Education about *Amaranthus*'s nutritional benefits and the provision of good packaging and storage is needed to make it attractive to buyers.
3. *Amaranthus* should be promoted in all malls to encourage or create awareness among those who do not patronise roadside vendors.
4. Studies on the dietary benefits of other varieties like *Amaranthus thumbegii* can be explored for its value-adding potential for improved nutrition security.
5. There is a need for effective implementation of some relevant activities that can help in encouraging the domestication of *Amaranthus.*
6. Higher ALP-supplemented *Ujeqe* will need improvement in the colour and taste of the supplemented samples for better consumer acceptability.
7. Future studies should analyze fiber content and the microbial properties of supplemented *Ujeqe* for shelf-life stability.
8. *Amaranthus* supplemented *Ujeqe* bread can be produced on a small-scale among street food vendors, and awareness of ALP-supplemented food products, including *Ujeqe,* can be disseminated via workshops, campaigns, or seminars. Such platforms can also address food-based approaches to tackling malnutrition, and issues of utilizing available indigenous food materials like *Amaranthus* in other indigenous staple foods.

APPENDICES

Appendix A

Consent Form

Respondent number: _______

_My name is Ruth. N. Olusanya, a full-time PhD registered student at the University of KwaZulu Natal. School of Agricultural Earth and Environmental Science (Food Security). I would like you to participate in this study, which is about, ***Utilization of Amaranthus leaf powder in wheat flour Ujeqe for alleviation of food and nutrition insecurity (rural communities, South Africa).*** Therefore, you will be required to participate in a survey, sensory evaluation *Amaranthus supplemented "Ujeqe" (steam bread*) and in focus group discussions.

It is essential to know:

- ✓ Participation in this study is voluntary, you can stop participating at any time during the study.
- ✓ There will be no form of payment for participating in the study.
- ✓ All information will be kept confidential and will only be used for this study.
- ✓ Over time the information provided will be destroyed when deemed necessary
- ✓ For further information about the study, please contact my supervisors Prof. Kolanisi at kolanisi@ukzn.ac.za and KolanisiU@unizulu.ac.za
- ✓ Dr. Ngobese ngobesen@uj.ac.za and Dr. Chinsamy Chinsamym@ukzn.ac.za

Declaration of the respondent.

I ____ (full name and surname) hereby confirm my understanding of the questionnaire and I understand that I will not be exposed to any risks during the study and that I may withdraw from participating at any point I wish to.

________________________ ________________________

Signature Date

____

Phone number

HSSREC Research Office UKZN

Govan Mbeki Building

Westville Campus

031 260 4557

E-mail mohunp@ukzn.ac.za

English version. Sensory evaluation rating scale section

Respondent No: _______

<u>Consumer Acceptability score card (English version)</u>

Name of respondent: ____

Sample: ____

Date: ____

Instructions:

- Before tasting, rinse, the mouth with water, repeat rinsing after tasting each sample.
- Taste from left to right.
- Mark with an **(X),** the face that bests suit your response to the statements below.

1. Colour

Dislike very much	Dislike slightly	Neither like nor dislike	Like slightly	Like very much

2. Aroma

Dislike very much	Dislike slightly	Neither like nor dislike	Like slightly	Like very much

3. Texture (fluffiness)

Dislike very much	Dislike slightly	Neither like nor dislike	Like slightly	Like very much

4. Taste

Dislike very much	Dislike slightly	Neither like nor dislike	Like slightly	Like very much

5. Overall Acceptability

Dislike very much	Dislike slightly	Neither like nor dislike	Like slightly	Like very much

Ngyabonga kakulu/ Thank you!!!!!!!!!!!!!

Appendix B

ZULU VERSION: - IMIBUZO YOKWAMUKELEKA KWEZIDLO EZINCANYANA EZENZIWE NGOMBILA.

Inombolo onikezwe yona: --------------------------------

Iminiyaka: ----------------- Ubulili: -----------------

Dwebela okufanele: Ngiqashiwe----------- Angiqashiwe-------

Inombolo ampulo: -------------------------------------

Ubulili: -------------------- Iminyaka: |__||__|

IMIYALELO

- Ngaphambi kokuba unambithe ukudla, yakaza umlomo ngamanzi aphambi kwakho.
- Hlola ukudla okuphambi kwakho. Shono ukuthi ucabangani ngendlela okunambitheka ngayo, iphunga, umbala, indlela okuzwakala ngayo emlonyeni kanye nendlela okuthanda ngayo nje. Khombisa lokhu ngokubeka uphawu [X] eduze kobuso obuqondene nomuzwa wakho
- Yakaza umlomo ngamanzi emva kokudla isidlo ngasinye. Ungayakaza futhi nanoma ngasiphi isikhathi ngenkathi uhlola lokudla.
- Uma unomubuzo ungabuza.

MAKA UBUSO OBUBODWA NGO ***(X)*** *OKUVUMELANA NESINQUMO SAKHO NGEZIHLOKWANA EZIBHALIWE*

UMBALA

Kubi impela | Kubi | Ngingakuthanda noma futhi ngingakuthandi | Kumnandi | Kumnandi impela

IPHUNGA

Kubi impela | Kubi | Ngingakuthanda noma futhi ngingakuthandi | Kumnandi | Kumnandi impela

UKUZWA NGESANDLA

Kubi impela | Kubi | Ngingakuthanda noma futhi ngingakuthandi | Kumnandi | Kumnandi impela

UKUZWA NGOMLOMO

Kubi impela	Kubi	Ngingakuthanda noma futhi ngingakuthandi	Kumnandi	Kumnandi impela

ISINQUMO JIKELELE

Kubi impela	Kubi	Ngingakuthanda noma futhi ngingakuthandi	Kumnandi	Kumnandi impela

NGIYABONGA!!!!!!!!!!!!!

Appendix C

Survey Questionnaire

Inform consent.

My name is Ruth Olusanya, a full-time PhD student at the University of KwaZulu Natal, discipline of (Food Security) School of Agricultural Earth and Environmental Science. I would appreciate you participate on a study on ***Utilization of Amaranthus leaf powder in wheat flour Ujeqe for alleviation of food and nutrition insecurity (rural communities, South Africa).*** As a participant, you will be required to kindly participate by responding to the questions below and, in doing so, it is essential to note that:

- ✓ Participation in this study is voluntary: you can stop participating at any time during the study.
- ✓ There will be no form of payment for participating in the study.
- ✓ All personal information will be kept confidential and eventually destroyed over time.
- ✓ The scientific information gathered will only be used for this study and will be published in public platforms such as university websites and scientific journals.

For further information about the study, please contact my supervisors.

Prof. Kolanisi at kolanisi@ukzn.ac.za and KolanisiU@unizulu.ac.za

Dr. Ngobese nomalingobese@gmail.com and Dr. Chinsamy Chinsamym@ukzn.ac.za

NGyabonga kakulu/ (Many thanks)

Appendix D

Questionnaire on the Utilization of *Ujeqe* (steamed bread) and

SECTION A: INFORMATION OF THE RESPONDENT

1.1 Indicate your age group in the box. Tick appropriately

18-25	
26-30	
31-40	
41-50	
51-60	
61-70	
≥71	

1.1.Indicate your race in the box. Tick appropriately

Black	
White	
Indian	
Other (specify)	

1.2.Gender. Tick appropriately

Male	
Female	
Other (specify)	

1.3.Level of education. Tick appropriately

Informal	
Primary	
Secondary	
Tertiary	

1.4.Employment Status. Tick appropriately

Unemployed	
Self-employed	

Government	
Private sector	

SECTION B: UTILISATION OF *AMARANTHUS* LEAFY VEGETABLES

1. Are you familiar with *Amaranthus* (*Imfino /pigweed/Hanekam/Thepe/Imbuya/Vowa*)?
   - Yes
   - No

   If yes, how do you know about it, and what are the other common names of *Amaranthus* do you know?

   ____

   ____

2. What is your thought about *Amaranthus?*
   Tick the one that applies from the option below.
   - Food plant only
   - A food and medicinal plant
   - A weed.
   - Medicinal plant only

3. Do you, or have you ever consumed *Amaranthus?*
   - Yes
   - No

4. If no to question 3. If encouraged to use *Amaranthus* as food for nutritional/health benefits, would you use it as food? Please tick one.
   - I would happily use it for food.
   - I will gladly use it.
   - I would try it at least once.
   - I am not sure.
   - I would not use it.

5. What part/form of *Amaranthus* have you consumed?
   - Fresh leaves,
   - Powdered leaf form
   - Roots
   - Seed flour
   - Boiled seeds
   - Others specify____

6. Who in your household mostly consumes *Amaranthus* vegetables?
   - Children

- Adult
- Both (Adult and Children)

7. Do young children like *Amaranthus* in their food?
   - Yes
   - No

8. How regular do you have *Amaranthus* for consumption?
   - Daily
   - Twice a week
   - Three times a week
   - One's a week.
   - One's a month.
   - Not regular

9. What is the leaf colour of the most consumed *Amaranthus* in your locality Tick appropriately?

Green	
Brown	
Red	
Specify another colour if any	

10. Is *Amaranthus* seed edible?
    - Yes
    - No
    - I don't know.

11. What do you do with the seeds of *Amaranthus?*
    - We throw it away.
    - We boil it and eat.
    - We pop it like popcorn and eat.
    - We do not eat it because it is not a food.
    - We save the seeds for next planting season.
    - Others specify.

12. What part of the *Amaranthus* do your locality eat as food? (Tick appropriately).

Leaves	
Stems	
Seeds	

Roots	
Every part is food	

Utilization of *Ujeqe*

13. Are you familiar with *Ujeqe?*
    - Yes
    - No

14. Is *Ujeqe* an indigenous food in your community.
    - Yes
    - No

15. What is the common ingredient used for the preparation of *Ujeqe?*

____

____

16. Do you eat *Ujeqe* as food or as snack and, how regular do you eat *Ujeqe?*

- Yes
- No

17. Why do you eat *Ujeqe?*

____

____

18. Can you briefly describe how *Ujeqe* is prepared in your community?

____

____

19. List the things you can eat *Ujeqe* with?

____

____

20. Do you think just eating plain wheat *Ujeqe* alone has health benefits? If yes specify

____

____

21. Would like to eat *Ujeqe* that is made with *Amaranthus* leaves powder for health benefits reasons?

Ethical clearance was obtained from the Ethics committee university of KwaZulu-Natal.

Due to the covid the research could not conduct the research within the stipulated time; hence, the ethical clearance expired, and recertification application was done which was granted. Both ethical clearances are presented in (Appendix E and F) the study.

Appendix E

UNIVERSITY OF
KWAZULU-NATAL

Inform consent.

My name is Ruth. N. Olusanya, I am a registered full-time PhD student in the discipline of Food Security School of Agricultural Earth and Environmental Science. At the University of KwaZulu Natal I would like to appreciate your participation in this research on ***the utilization of Amaranthus leaf powder to fortify wheat flour for Ujeqe (steamed bread) for the alleviation of food and nutrition insecurity of rural communities in South Africa***. As a key informant, you will be required to kindly participate by responding to the questions that would be asked around the value chain of Amaranthus and, in doing so, it is essential to note that:

- ✓ Participation in this study is voluntary: you can stop participating at any time during the study.
- ✓ There will be no form of payment for participating in the study.
- ✓ All personal information will be kept confidential and eventually destroyed over time.
- ✓ The scientific information gathered will only be used for this study and will be published in public platforms such as university websites and scientific journals.

For further information about the study, please contact my supervisors.

Prof. Kolanisi at kolanisi@ukzn.ac.za and KolanisiU@unizulu.ac.za

Dr. Ngobese nomalingobese@gmail.com and Dr. Chinsamy Chinsamym@ukzn.ac.za

SECTION A: DEMOGRAPHIC INFORMATION OF THE RESPONDENT

1. Indicate your age group in the box. Tick appropriately

18-25	
26-30	
31-40	

41-50	
51-60	
61-70	
≥71	

2. Indicate your race in the box. Tick appropriately

Black	
White	
Indian	
Other (specify)	

3. Gender. Tick appropriately

Male	
Female	
Other (specify)	

4. Level of education. Tick appropriately

Informal	
Primary	
Secondary	
Tertiary	

5. Employment Status. Tick appropriately

Unemployed	
Self-employed	
Government	
Private sector	

KEY INFORMANT GENERAL KNOWLEDGE ABOUT THE AMARANTHUS VALUE CHAIN

1) Are there varieties of Amaranthus? If yes, what variety do you grow, can you also Indicate the variety of Amaranthus common to your locality?
2) Do you own a farmland/garden for Amaranthus? If a farmland, what is the size of the farmland of your Amaranthus vegetables in hectares? If it is a home garden where precisely, do you mostly cultivate the Amaranthus vegetable and what size is the garden.
3) Do you cultivate the Amaranthus vegetable by yourself? What kind of labor do you mostly use and, what aspect of work do other family members do on the amaranth farm?
4) Do you grow Amaranthus vegetables majorly for, household consumption alone? Or what season is Amaranthus mostly cultivated, harvested, and consumed?
5) How long does it take for Amaranthus vegetables to mature before harvesting? Also, what are the stages of maturity, and what (physical characteristics) are visible on the plant before harvesting your Amaranthus leafy vegetables?
6) What time of the day do you harvest your Amaranthus vegetables and why such, a time? Do you supply immediately to your buyers?
7) If cultivated for selling, how long, have you been cultivating and supplying Amaranthus vegetables? And what is the demographic of your buyers, include their race age group, or company if possible.
8) Which markets do you mostly supply your Amaranthus, and how far is the market in kilometers from your farm?
9) After harvesting the Amaranthus, how long do you have to wait for the Amaranthus vegetables to be transported and what means of transport do you use? When do you deliver your Amaranthus vegetables to the market? And do you own or hire the transport?
10) Are there times you lack where to supply your Amaranthus and how do you preserve the unsold Amaranthus vegetables, do you process the leaves of Amaranthus?

Questions on the challenges/successes that are encountered by farmers and sellers of Amaranthus.

a) What are the problems/limitations you are encountering in farming or selling your Amaranthus? And how do you think these problems can be solved?
b) What is the major strength or possibilities in the Amaranthus value chain?
c) What is the amaranth farmer’s current contextual situation?

d) What are the limitations affecting a small-scale farmer in KZN province, especially when trying to enhance a sustainable livelihood?
e) What can generally be done to enhance small-scale farmers' capital?

Section Questions for the Formal Marketers of Amaranthus

1. Do you sell indigenous leafy vegetables in your company? if yes could you please give a rundown list of the indigenous vegetables sold in your company and what is the cheapest and most sold indigenous vegetables in your company?
2. Does your company have farmlands for all the indigenous vegetables in your mall, or you are just a seller of them? Does your company cultivate/ sell Amaranthus? If cultivated, what is the size of your farmland, if not, where do you normally get a supply of the Amaranthus you are selling? Can you kindly give a general knowledge of one of the vegetables particularly the (Amaranthus)?
3. What is the common race/ socio-economic status of those who buy or consume your Amaranthus as a food plant in your locality?
4. When you bundle your Amaranthus vegetables, do you trim off the roots and stems? If yes, why? And if not, why not?
5. What is your Amaranthus bundle size in kilograms and how much does it cost per bundle?
6. Also, how often in a day, week, and month do you sell Amaranthus, and how long does it last before it is sold are there times you have leftovers, if yes, what do you do with them?
7. What package do you use for packaging your Amaranthus vegetables if no packaging why?
8. As an Amarant seller, what problems do you encounter in selling your Amarant vegetables?
9. Apart from the leafy Amaranthus, what other forms of Amaranthus do you sell, and are there any Amaranthus-based food products in your mall?
10. Do you consume the Amaranthus yourself or just sell it? If not, why? and if yes, what part of the Amaranth plant do you consume and what common ingredients/methods are used to make Amaranth food-based products?
11. Do you know any, or have you ever had health challenges with the consumption of Amaranthus? If yes specify the health challenges
12. Are there any cultural beliefs and rituals associated with Amaranthus in your community? If yes, describe these cultural beliefs and rituals.

Questions for Informal marketers of Amaranthus

1. Can you please provide us with a general knowledge of the Amaranthus plant? Do you cultivate/sell Amaranthus? If not, where do you normally get the Amaranthus you are selling? Kindly indicate the races and the socio-economic status of the buyers and consume your Amaranthus as a food plant in your locality.

2. Also, how often in a day, week, and month do you sell Amaranthus? Are you depending on Amaranthus's business as a means of living?

3. What is your Amaranthus bundle size in kilograms and how much does it cost per bundle? When you bundle your Amaranthus vegetables, do you trim off the roots and stems? If yes, why?

What package do you use for packaging your Amaranthus vegetables if no packaging why?

4. As an Amaranthus seller, what problems do you encounter in selling your Amaranthus vegetables?

5. Do you usually sell all your Amaranthus daily?

Do you consume the Amaranthus yourself or you are just selling it? If not, why? And if yes, what part of the Amaranth plant do you consume and what common ingredient/method do you use to make Amaranth food-based products?

6. Do you know, or have you ever had health challenges with the consumption of Amaranthus if yes specify the health challenges

7. Are there any cultural beliefs and rituals associated with Amaranthus in your community? If yes, describe these cultural beliefs and rituals.

Appendix F

UNIVERSITY OF
KWAZULU-NATAL
INYUVESI
YAKWAZULU-NATALI

21 October 2019

Mrs Ruth Nachamada Olusanya (215081315)
School Of Agri Earth & Env Sc
Pietermaritzburg Campus

Dear Mrs Olusanya,

Protocol reference number: HSSREC/00000435/2019
Project title: Utilization of Amaranthus leaf powder to fortify wheat flour for jeqe (steamed bread) for the alleviation of food and nutrition insecurity of rural communities in South Africa

Full Approval – Expedited Application

This letter serves to notify you that your application received on 12 September 2019 in connection with the above, was reviewed by the Humanities and Social Sciences Research Ethics Committee (HSSREC) and the protocol has been granted **FULL APPROVAL**

Any alteration/s to the approved research protocol i.e. Questionnaire/Interview Schedule, Informed Consent Form, Title of the Project, Location of the Study, Research Approach and Methods must be reviewed and approved through the amendment/modification prior to its implementation. In case you have further queries, please quote the above reference number. PLEASE NOTE: Research data should be securely stored in the discipline/department for a period of 5 years.

This approval is valid for one year from 21 October 2019.
To ensure uninterrupted approval of this study beyond the approval expiry date, a progress report must be submitted to the Research Office on the appropriate form 2 - 3 months before the expiry date. A close-out report to be submitted when study is finished.

Yours sincerely,

[redacted]

pp **Dr Rosemary Sibanda (Chair)**

/dd

Humanities & Social Sciences Research Ethics Committee
Dr Rosemary Sibanda (Chair)
UKZN Research Ethics Office Westville Campus, Govan Mbeki Building
Postal Address: Private Bag X54001, Durban 4000
Website: http://research.ukzn.ac.za/Research-Ethics/

Appendix G

UNIVERSITY OF KWAZULU-NATAL
INYUVESI YAKWAZULU-NATALI

18 September 2021

Mrs Ruth Nachamada Olusanya (215081315)
School Of Agri Earth & Env Sc
Pietermaritzburg Campus

Dear Mrs Olusanya,

Protocol reference number: HSSREC/00000435/2019
Project title: Utilization of Amaranthus leaf powder to fortify wheat flour for jeqe (steamed bread) for the alleviation of food and nutrition insecurity of rural communities in South Africa

Approval Notification – Recertification Application

Your request for Recertification dated 09 September 2021 was received.

This letter confirms that you have been granted Recertification Approval for a period of one year from the date of this letter. This approval is based strictly on the research protocol submitted and approved in 2019.

Any alteration s to the approved research protocol i.e. Questionnaire/Interview Schedule, Informed Consent Form, Title of the Project, Location of the Study must be reviewed and approved through the amendment /modification prior to its implementation. Please quote the above reference number for all queries relating to this study.

PLEASE NOTE: Research data should be securely stored in the school/department for a period of 5 years

All research conducted during the COVID-19 period must adhere to the national and UKZN guidelines.

HSSREC is registered with the South African National Research Ethics Council (REC-040414-040).

Yours sincerely,

[redacted]

Professor Dipane Hlalele (Chair)

/dd

Humanities & Social Sciences Research Ethics Committee
UKZN Research Ethics Office Westville Campus, Govan Mbeki Building
Postal Address: Private Bag X54001, Durban 4000
Tel: +27 31 260 8350 / 4557 / 3587
Website: http://research.ukzn.ac.za/Research-Ethics/