DEVELOPMENT OF A BAMBARA GROUNDNUT AND AMARANTH VEGETABLE-BASED MEAT ALTERNATIVE FOR THE ZIMBABWEAN SCHOOL FEEDING PROGRAM

A dissertation submitted in partial fulfilment of the requirements for the Master of Science Degree in Food Security and Sustainable Agricultural Policy

Bindura University of Science Education

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DECLARATION

I hereby declare that the research project entitled "**Development of a Bambara groundnut and amaranth vegetable-based meat alternative for the Zimbabwean school feeding program"** submitted to Bindura University of Science Education, Department of Agricultural Economics, Education and Extension is a record of an original work done by me under the guidance and supervision of **Dr. L. Musemwa** and this work is submitted in partial fulfilment of the requirements for the award of a Master of Science Degree in Food Security and Sustainable Agriculture. The results embodied in this thesis have not been submitted to any University or Institute for the award of any degree of diploma.

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DEDICATION

This research project is dedicated to my children and my siblings. May you have the courage to follow your dreams and achieve greater than I have.

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ABSTRACT

Malnutrition remains a critical health and nutritional issue globally. The United Nations Hunger Task Force (UNHTF) has outlined seven recommendations to achieve the first Sustainable Development Goal (SDG) of eradicating hunger. Among these strategies is the implementation of School Feeding Programs (SFPs) using locally sourced, cost-effective, and eco-friendly foods instead of imported aid. In Zimbabwe, the government has adopted several policies to enhance the health of children and communities, such as the 2016 National School Feeding Program (NSFP). Another comprehensive policy is the Food and Nutrition Security Policy (FNSP), which aims to ensure food and nutrition security for all citizens, especially the vulnerable, while respecting cultural values and promoting family dignity. For many children from food-insecure households, school meals are their primary source of essential nutrients. The government's efforts, particularly through the NSFP, are commendable but insufficient given the reality on the ground. The heavy reliance on a few staple crops is leading to the decline of various crops, including orphan legumes, which are crucial for protein and nutritional security. These staple crops are increasingly unable to adapt to changing climatic conditions. Orphan legumes, however, are climate-resilient and support sustainable livelihoods. This project addresses these issues.

The primary aim of this project was to develop a meat alternative based on Bambara groundnut and amaranth vegetables that meet the nutritional standards of the Zimbabwe School Feeding Program. The objectives were threefold: first, to analyze the proximate composition of the Bambara groundnut and amaranth vegetable-based meat alternative; second, to evaluate the sensory properties of the same; and third, to assess consumer acceptability of the developed product. Bambara groundnuts and amaranth vegetables were sourced from the local Mbare farmers' market, milled, and blended in three different ratios. The blends underwent a sensory evaluation to assess appearance, colour, texture, and overall acceptability. They were also analysed for protein, carbohydrate, fibre, and mineral content using standard methods. Consumer acceptability was tested using a 9-point hedonic scale by a panel of students and staff from three local schools in the Epworth-Mabvuku district.

The meat substitute's crude protein, fat, fibre, and ash content increased with a higher ratio of Bambara groundnut. Sensory evaluation revealed no significant difference ($p>0.05$) in taste, colour, aroma, texture, appearance, and overall acceptability between the BGN-amaranth meat substitute and existing soya chunks.

The development of the BGN-amaranth meat substitute was successful, providing a nutritious option high in protein, fat, and minerals. This meat substitute has the potential to enhance the nutritional quality of the Zimbabwe School Feeding Program. While previous studies indicated low consumer acceptance of vegetable-based meat substitutes, this study found the BGN-amaranth substitute to be acceptable. However, further sensory evaluations with a more diverse group of students and parents are needed. Overall, this study suggests that combining BGN and amaranth can create complementary foods that significantly address child malnutrition, including protein-energy malnutrition (PEM), in sub-Saharan Africa, particularly Zimbabwe.

Keywords: malnutrition, school feeding, meat substitute, proximate analysis, sensory evaluation

LIST OF ACRONYMS AND ABBREVIATIONS

BD	Density
BGN	Bambara Groundnut
PBMA	Plant-Based Meat Alternatives
SCF	Supercritical Fluid Extrusion
SDG	Sustainable Development Goal.
SFP	School Feeding Programs
SP -	Swelling Power
TVP	Texturized Vegetable Protein
UNHTF	United Nations Hunger Task
WBC	Water Binding Capacity
WHO	World Health Organisation

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CHAPTER 1

INTRODUCTION

1.1 Background of the study

According to ZIMVAC (2020), about 75% of households in rural Zimbabwe are poor, 23% of them are considered very poor and they spend more than half of their income on food. Additionally, 33% of households experience food deprivation. Around 31% of Zimbabwe's rural population which is about 2.88 million people required urgent assistance to improve food security, and to tackle acute malnutrition. Food shortages heavily influence the quality of education(FAO, et al., 2018). In countries like Zimbabwe, food insecurity and inadequate nutrition negatively impact school children and the educational system (Dei, 2014). According to Chinyoka(2014), malnutrition is particularly detrimental to students from economically disadvantaged backgrounds, leading to high dropout rates.

The United Nations Hunger Task Force (UNHTF) proposed seven recommendations to achieve SDG 1Zero Hunger, including implementing School Feeding Programs (SFPs) that use locally produced, affordable, and environmentally friendly foods instead of imported food aid. SFPs are seen as a tool to improve both education and agriculture by increasing school attendance, especially for girls, and stimulating the demand for locally produced foods. The Zimbabwean School Feeding Program aims to provide daily meals to primary school children to enhance food security and nutrition. However, the program struggles to source adequate and affordable protein. Reuben (2017) highlights that funding constraints are a significant obstacle to effective school feeding programs in developing countries, including Zimbabwe(Reuben, 2017). Sustainable strategies and policies are needed to expand and maintain these programs beyond donor support (Sanousi, 2019).

Overly relying on staple crop products is leading to the decline of diverse crops, especially orphan legumes, which are crucial for protein and nutritional security. These staple crops are increasingly less adaptable to changing climatic conditions. Conversely, orphan legumes are climate-resilient and support sustainable livelihoods. Research on these crops, despite some progress, has not yet matched the status of major commercial crops. There is a need for more extensive research and promotion of orphan legumes due to their vast genetic resources and economic potential (Popoola, et al., 2023).Achieving food security is essential, but ensuring nutritional security is equally crucial. Efforts to maintain a healthy global population must address both paradigms(Misselhorn, et al., 2012). Merely satisfying hunger through caloric intake is insufficient; balanced nutrition is necessary to prevent hidden hunger and its long-term damage. Animal proteins are scarce in Sub-Saharan Africa (SSA), necessitating the exploration of alternative protein sources. Legumes, or pulses, are nutrient-rich and provide essential amino acids, making them valuable for food security. Bambara nut, in particular, is a highly nutritious pulse that has been underutilized. Renewed interest in pulses for nutrient security presents an opportunity for Bambara nut to emerge as a key resource in combating malnutrition in SSA. This research project explores Bambara groundnut's potential for food and nutritional security, including its characteristics, production, utilization, constraints, and improvement efforts

1.2 Statement of the Problem

Dei (2014) notes that children as young as six months old are the immediate victims of household food insecurity and poverty. ZIMVAC (2019) found that many schoolchildren suffer from malnutrition, evidenced by stunting and short-term hunger. The World Food Program reports that in 2022, about 2.6 million people, including 1.9 million children, needed humanitarian aid in Zimbabwe due to multiple crises such as floods, drought, food and nutrition insecurity, the COVID-19 pandemic, and economic instability(ZIMVAC, 2019).

To combat food insecurity and malnutrition, the Zimbabwean government has implemented several policies, including the 2016 National School Feeding Program (NSFP), which was integrated with the Curriculum Framework (2015-2022) to promote health education, ensure a "safe and sanitary school environment, and provide school-based health and nutrition services"(Bakani, 2020). The Government aims to guarantee adequate food and nutrition security for all, especially the most susceptible while respecting cultural norms and preserving the dignity of families through the Food and Nutrition Security Policy (FNSP) of Zimbabwe(GoZ, 2018).

In Zimbabwe, the focus has shifted from the importance of school feeding to the design and implementation of effective programs (WFP, 2017). The need for the intervention has grown over the past years due to persistent food insecurity and malnutrition among school-aged children, exacerbated by climate change and economic shocks. According to the Government of

Zimbabwe, 2,716,363 primary school children benefit from various school feeding programs. For many of these children, a school meal is their primary source of essential vitamins and micronutrients(ZIMVAC, 2022). Despite the government's significant contributions through the NSFP, the program only partially addresses the needs on the ground.

Factors such as climate change, growing populations as well as exhaustive monoculture farming, and depletion of natural resources are significant challenges to the global agro-food system. In addition, dependence on a few major crops leads to inadequate nutrition due to poor diets which leads to micronutrient deficiencies(Wijerathna-Yapa & Pathirana, 2022). Diversifying agricultural practices as well as food systems is a viable tactic for improving food security as well as and nutritional wellbeing of communities. Underutilized crops like Bambara groundnut and amaranth, which are drought-tolerant and nutritionally rich, offer promising solutions. Amaranth is valued for its high-quality protein, dietary fibre, and essential nutrients, making it suitable for climate adaptation strategies and food security in arid regions of Africa(Katoch, 2020).

Despite its potential, the crop remains underutilized due to resource limitations, knowledge gaps, and inadequate research and policies. Continued study is needed to fully realize its potential and promote its benefits for food and nutrition security(Tan, et al., 2020). Given the increasing global demand for plant-based meat alternatives, this project aims to develop a meat substitute using locally available ingredients, such as roundnuts and amaranth vegetables, to enhance the protein content of meals.

1.3 Research Objectives:

1.3.1 Main Objective

To develop a Bambara groundnut and amaranth vegetable-based meat alternative that meets the nutritional requirements of the Zimbabwe School Feeding Program.

1.3.2 Specific Objectives

i. To determine the proximate analysis of the Bambara groundnut and amaranth vegetable-based meat alternative.

ii. To determine sensory parameters of the Bambara groundnut and amaranth vegetable-based meat alternative.

iii. To assess consumer acceptability of the Bambara groundnut and amaranth vegetable-based meat alternative

1.4 Research questions

i. What is the proximate analysis of the roundnut and vegetable meat alternative?

ii. What are the learners' perceptions of the sensory parameters of the proposed roundnut and amaranth vegetable-based meat alternative?

iii. Is the roundnut and amaranth vegetable-based meat alternative accepted by the learners?

1.5 Hypothesis

A plant-based meat alternative made from a blend of roundnuts and amaranth vegetables provides a nutritious, affordable and culturally acceptable protein source for the Zimbabwean school feeding program, leading to increased food and nutrition security amongst learners.

1.6 Significance of the Study

This research aims to address the challenge of sourcing affordable and sustainable protein for the Zimbabwean School Feeding Program by promoting plant-based foods, thereby reducing the environmental impact of meat production. The study will provide valuable insights into the potential of sustainable and affordable protein sources for vulnerable populations in Zimbabwe, contributing to the body of knowledge in this field. The findings are expected to guide policy decisions for the future direction of the national feeding program, potentially enhancing food security and nutrition across Zimbabwe. Specifically, the study will contribute to the following areas:

Improved Nutrition: By developing a nutritious and affordable protein source for the school feeding program, the study shall develop a product that improves the overall nutrition of students who often lack access to sufficient food.

Food Security: The creation of a plant-based meat alternative will help combat food insecurity, particularly in rural areas where agriculture is the primary economic activity.

Health Benefits: Plant-based meat substitutes benefit in reduced risk of chronic diseases such as heart disease, diabetes, and cancer.

Environmental Sustainability: Consumption of plant-based meat alternatives lessen the environmental impact of animal agriculture, a major contributor to greenhouse gas emissions and deforestation.

1.7 Scope and Limitations of the Study

1.7.1 Scope of the Study

This research project is focused on developing a plant-based meat alternative using roundnuts and amaranth vegetables for the Zimbabwean School Feeding Program. The study will concentrate on evaluating the nutritional value, sensory qualities, and consumer acceptance of the prototype product. The research will be confined to laboratory experiments, pilot testing, and surveys conducted with a selected group of participants within Zimbabwe.

1.7.2 Limitations of the Study

A major limitation of this study is its exclusive focus on roundnuts and amaranth vegetables as the primary ingredients for the plant-based meat alternative, excluding other potential ingredients such as soybeans and peas. Additionally, the sensory evaluation and consumer acceptance tests will be conducted with a limited group of participants, which may not reflect the general population's perception of the product. Lastly, the findings of this research cannot be generalized beyond Zimbabwe due to differences in culture, preferences, and dietary habits among various populations.

CHAPTER 2

LITERATUREREVIEW

2.1 Introduction

Despite numerous attempts at nutrition interventions, malnutrition persists, especially in low-income nations, posing a threat to their economic progress due to hidden hunger. As part of efforts to combat hunger, the World Health Organization (WHO) has advocated for the adoption of African leafy vegetables and orphan legumes since 2009(Ojiewo, et al., 2015). This agricultural-based intervention utilizes locally available resources, making it cost-effective. In Zimbabwe, malnutrition problems that are prevalent among children are protein-energy malnutrition (PEM) and micronutrient deficiency and these are mainly due to insufficient diets. Various strategies like dietary diversification, fortification, and supplementation have been employed to address these issues. Combining Bambara groundnut (BGN) and amaranth may offer a complementary solution to combat these forms of malnutrition.

2.2 Bambara Groundnut

Bambara groundnut whose scientific name is *Vignasubterranea*is a Fabaceae family that is originally from Africa and thrives in semi-arid regions. It's valued for its nutritional richness, with a balanced composition of macronutrients and mineral content(Bamshaiye, et al., 2011).The legume is primarily carbohydrate, about64.4%, and about 23.6% protein. It also contains6.5% of fat and has a fibre content of 5.5% and is rich in minerals (Tan, et al., 2020).

Despite its potential, Bambara groundnut is mostly grown on a very much smaller scale, as compared to other cash crops. Women are mostly responsible for growing and processing the crop, and they practice mostly subsistence farming. The challenges include limited knowledge of improved cultivation, processing, and utilization methods.

2.2.1 Bambara groundnut production in Sub-Saharan Africa

Bambara groundnut originates from Africa, particularly the central and western regions. It is extensively cultivated across sub-Saharan Africa. Its popularity is higher in arid regions susceptible to drought due to its ability to yield well under such conditions, providing a reliable food source for farmers. Africa produces around 0.3 million tons of Bambara groundnut annually (Tan, et al., 2020). Nigeria is the top producer with around 0.11 million tons, and Niger with 30,000 tons.

Musa et al., (2016) noted that the high genetic variability in landraces of Bambara groundnut offers significant potential for crop improvement. Most improved varieties grown today are selected landraces that offer better yields, and improved seed as well as flour quality. These varieties are believed to be drought-resistant. Typically, Bambara groundnut is planted as a secondary crop, for family use. Due to its limited market demand, maintaining yield stability is prioritized over increasing grain yield to ensure food security.

Like other legumes that fix atmospheric nitrogen, Bambara groundnut can enhance nitrogen levels of soil, thus it is excellent for intercropping and crop rotation. The legume is often grown alongside cereals and tubers that primarily provide carbohydrates in diets. Its use in crop rotations helps maintain soil fertility and disrupt pest and disease cycles, which benefits resource-poor farmers who might not afford fertilizers and pesticides(Chelangat, et al., 2023).

2.2.2 Nutritional composition of Bambara Groundnut

With an increasing shift towards plant-based diets, Bambara groundnut emerges as a vital protein source. Its nutrient profile includes carbohydrates, proteins, lipids, and minerals, making it a suitable complement to cereals deficient in lysine and methionine. However, variations in its lipid and amino acid content warrant attention for balanced nutritional benefits (Effa & Uko, 2017).

2.2.2.1 Starch (Carbohydrates)

Carbohydrates in Bambara groundnut make up about 60% of the total seed's mass (Kendabie, et al., 2020). The carbohydrates are mostly complex polysaccharides, having starch content of up to 49.5% of the total carbohydrate content. However, factors such as genetics, environment and maturity stage can affect the seeds’ starch content which then varies significantly from 22 to 49.5% weight(Mwale, et al., 2017). The starch in raw Bambara groundnut is often indigestible and complex compared to more digestible starch in cooked Bambara groundnut (Amoah , et al., 2023).

2.2.2.2 Protein

Bambara groundnut contains a protein content that ranges from 9.6 to 40%, averaging around 24%(Azman-Halimi, et al., 2019). The variances are caused by differences in genetics, climatic environments, and nitrogen conversion factors. The quality of protein, which is influenced by the structure and digestibility of amino acids is as important as protein quantity. Bambara groundnut cultivars show variability in amino acid profiles, with glutamic acid being the most abundant (Mubaiwa et al., 2018).

2.2.2.3 Lipids

Bambara groundnut's lipid content varies widely between 1.4 and 9.7%(Bamshaiye, et al., 2011). Most of the fatty acids are unsaturatedomega-6 namely oleic and linoleic acids, and linolenic acid which is available in low concentrations. Bambara groundnut is rich in unsaturated fatty acids, which are beneficial for health but increase susceptibility to oxidation and rancidity, which should be considered when selecting lipid composition traits.

2.2.2.4 Minerals

Bambara groundnut is rich in minerals such as potassium, magnesium, phosphorus, zinc, and iron. Hillocks, et al., (2012) found these minerals in higher levels compared to the usually consumed legumes sugar beans, although the amounts vary by variety and growing conditions. According to (Gwala, et al., 2021)the bioavailability and concentration of minerals such as zinc, magnesium, iron and calcium in the legume are affected by the location of the minerals in the seeds as well as processing techniques and storage. Despite being a good mineral source, Bambara groundnut alone is unlikely to meet an individual's dietary mineral needs.

2.2.2.6 Dietary Fiber

Rich in dietary fibre, Bambara groundnut provides insoluble fibre, aiding digestive health. Its fiber content varies with maturity and processing methods(Chelangat, et al., 2023).

2.2.2.7 Anti-nutritional Factors

Like other legumes, Bambara groundnut contains several anti-nutritional factors (ANFs) that can negatively impact nutrient digestion and bioavailability (Nweke & Emeh , 2013). Tannins are found in the seed coat and darker seeds. They have antioxidant properties and can reduce the bioavailability of minerals, starch, and proteins (Mubaiwa , et al., 2018). These complexes can also inhibit digestive enzymes and impart bitterness, affecting palatability. Additionally, some dietary fibres, are known to reduce mineral bioavailability and affect the cooking ability of the legume.

2.2.3 Processing of Bambara Groundnut to Increase Nutritive Value and Utilization

2.2.3.1Bambara groundnut traditional processing methods and use

After harvesting, BGN is typically dried as a preservation method to ensure long-term storage, extend its shelf life and ensure its availability during food shortages(Mwale, et al., 2017). The dried seeds are often milled for flour or soaked in water to rehydrate them for consumption. Traditional processing methods, often performed at the household level using basic equipment, impact the seeds' nutritional, sensory, and functional properties. Traditionally, the legume is often boiled or roasted to be consumed as a side dish or snack(Mwale, et al., 2017). It is also used to prepare numerous traditional foods across Africa. When combined with cereals like maize and millet, it improves protein quality. In Zimbabwe, the popular dish "mutakura," made from Bambara groundnut, maize, and other legumes, is a dietary staple for many households.

2.2.3.2Advanced Processing Technologies

Beyond traditional methods, advanced processing techniques can enhance the nutritional quality and improve the value addition of Bambara groundnut. Techniques like irradiation, infrared heating, and autoclaving can improve the seeds' nutritional properties and physicochemical characteristics. Gamma-irradiation, for instance, degrades starch and reduces cooking time by increasing cell wall permeability. This method also alters protein structure and functionality(Nwadi, et al., 2020).

2.2.4The use of Bambara groundnut

2.2.4.1Traditional food uses of Bambara groundnut

Traditionally, the legume is often boiled or roasted to be consumed as a side dish or snack (Mwale, et al., 2017). It is also used to prepare numerous traditional foods across Africa. When combined with cereals like maize and millet, it improves protein quality. In Zimbabwe, the popular dish "mutakura," made from Bambara groundnut, maize, and other legumes, is a dietary staple for many households.

2.2.4.2The use of Bambara groundnut in the processing of foods

Advancements in processing expertise and food technology along with growing consumer lifestyle changes that demand convenience foods, have caused an increase in the disposal of processed foods (Vurayai, et al., 2011). However, excessive processing of foods often leads to the loss of essential nutrients. To address nutrient deficiencies, food fortification is mandated in many countries. Bambara groundnut, due to its nutritional quality and affordability, is a promising ingredient for food fortification, offering a holistic approach to improving diets and utilizing underused plant species.

2.2.4.3Bambara groundnut in staples such as bread

Incorporating legume flour, such as Bambara groundnut flour, into bread and wheat noodle recipes can enhance their nutritional quality by improving protein content and reducing ANFs. However, Bambara groundnut flour lacks gluten, which affects the texture of leavened bread. Appropriate substitution levels are crucial for balancing improved nutrition and consumer acceptability, making these products effective in combating nutrient deficiencies(Nedumaran, et al., 2015).

2.2.4.4Bambara groundnut in snacks

Bambara groundnut flour can be used to fortify snacks like biscuits and crackers. The inclusion of this flour can vary depending on the formulation and production methods. Consumer preferences are considered during new research and product development to maximize the benefits of food fortified with Bambara groundnut (Mubaiwa , et al., 2018).

2.2.4.5Complementary or weaning Foods

Complementary foods usually lack essential amino acids and micronutrients having only starch and fibre in high quantities (Smith, 2019). Studies have shown that incorporating Bambara groundnut into complementary foods can significantly enhance their nutritional quality.

2.2.4.6 Beverages: Milk and Fermented Drinks

According to Halimi, et al., (2019), the demand for plant-based milk is rising due to the inaccessibility of dairy milk, dietary needs, and increased consumer demand for plant-based diets. Bambara groundnut can be used to produce vegetable milk and yoghurt, although optimizing sensory and physicochemical properties is necessary for wider consumer acceptance.

2.2.4.7Bambara Groundnut as a Functional Ingredient

Bambara groundnut starch and protein have functional properties that can be utilized in various food and non-food applications. Improving these properties could increase the crop's applications and demand, potentially benefiting producers (James , et al., 2018).

Bambara groundnut holds promise in addressing food insecurity and malnutrition, with its nutritional richness and adaptability. Overcoming utilization barriers and implementing value chain improvements are essential steps towards maximizing its contribution to food and nutrition security.

2.3 Amaranth vegetable

Amaranthus L. is a type of herbaceous plant that is known for utilizing C4 photosynthesis, which is more efficient in hotter climatic environments, compared to the more common C3 photosynthesis. This genus includes approximately 70 species, which are divided into three subspecies. These species encompass both cultivated varieties, which are grown for their edible leaves and grains. The wild types are found in various natural habitats. The amaranth vegetable is highly nutritious, containing protein, dietary fibre, vitamins, minerals, and antioxidants (Kanensi, et al., 2011).

2.3.1Nutrition

2.3.1.1 Nutritional Benefits

Amaranth leaves and seeds are widely consumed as leafy vegetables across many African countries, as it is an inexpensive source of protein and vitamins (Aderibigbe, et al., 2020). Both the leaves and seeds of amaranth have been extensively analyzed for their nutritional value, revealing a rich protein structure (Becker et al., 1981). As put by Gambus, et al., (2009) the protein profile of amaranth closely aligns with FAO/WHO recommendations for a sufficient diet. Amaranth has a protein score of 74, higher than wheat (47), soybeans (68-89), rice (69), and maize (35), indicating its superior protein quality(Alemayehu, et al., 2015). It is particularly rich in lysine, an amino acid often deficient in cereals like maize, wheat, and rice, including sulfur-rich amino acids often not found in other legumes. This makes amaranth an excellent supplement for improving the nutritional quality of diets (Schoenlechner, et al., 2010).

The high lysine, arginine, and histidine content in amaranth seeds makes them valuable for treating malnutrition in children. Additionally, amaranth seeds are rich in calcium, iron, sodium, and vitamins, supporting daily nutrient intake (Pedersen, et al., 1987). They also have expressively higher protein and fat content when compared to cereals like maize, sorghum and wheat and their overall nutritional value surpasses that of milk, soybeans, wheat, and maize (Brenner, 2002).

Amaranth is rich in bioactive compounds with strong antioxidant properties and its fat, contains unsaturated fatty acids like linoleic acid, which are highly beneficial nutritionally(Repo-Carrasco-Valencia, et al., 2009). Being gluten-free, the vegetable is gaining popularity, especially among individuals with gluten intolerance or celiac disease. Its nutritional profile makes it suitable for children, athletes, diabetics, and people with gluten or lactose intolerance(Valcárcel-Yamani & Lannes, 2012).

Amaranth seeds also provide significant amounts of micro and macro-elements(Piłat, et al., 2016). They are especially rich in iron and calcium, whose amounts are higher in amaranth than in cereals. A 100-gram serving contains 341.9 mg of potassium, 0.9g of zinc and 66 mg of magnesium(Kachiguma, et al., 2015). Consumption of 100g of amaranth provides the daily requirement for minerals such as calcium, iron, zinc and others (Gajewska, et al., 2002). The seeds are also low in sodium, making them suitable for people with hypertension or excess weight. In addition, the vegetable is a rich source of vitamins such as thiamine, niacin, and riboflavin(Niro, et al., 2019).

2.3.1.2 Anti-nutritional Factors

(Skwarylo-Bednarz, et al., 2020) state that amaranth seeds contain anti-nutritional factors that alter the vegetable’s nutritional value. However, they can be deactivated by heat. Despite these anti-nutritional factors, proper processing can mitigate their effects, making amaranth a highly beneficial food source(Prakash & Pal, 1991).

2.3.2 Amaranth food uses

Several countries use amaranth as an essential part of their traditional diets therefore it has the potential to increase its market share through value addition and the development of new products. Presently amaranth seeds are cracked to make candy, or the flour is mixed with honey to make a snack bar known as “Alegria” in Mexico and Peru respectively(Emire & Arega, 2012). Amaranth flour can also be used to make breakfast cereals and crackers, bread, alcoholic beverages and weaning porridges for babies(Rastogi & Shukla, 2013). Nutrition specialists encourage the consumption of amaranth by people living with HIV/AIDS as its high nutritional composition boosts the anti-retroviral drug’s effectiveness(Aswal & Bisht, 2017). With further research, there is potential for several commercial products to be developed from grain amaranth, such as breakfast cereals, breads and even pasta (Hackman & Myers, 2003).

3.3.3 Production of Amaranth in African countries

Countries in East Africa cultivate amaranth as a domesticated vegetable (Emire & Arega, 2012). Amaranth is an easy-to-grow vegetable that is nutritious and serves as rich food for communities that rely on subsistence farming(Emire & Arega, 2012). Although in Tanzania amaranth is considered an important vegetable, it is grown on a small scale (Ochieng, et al., 2019). Factors that affect smallholder farmers' cultivation of amaranth in Africa, Zimbabwe in particular, include challenges in acquiring land, expensive labour costs and insufficient marketing and irrigation. (Emokaro, et al., 2007). Amaranth is mainly produced by smallholder farmers who have no sturdy market linkages to buyers resulting in decreased potential. This then poses an opportunity for policymakers in Africa and their stakeholders to improve the vegetable's market share. This will positively contribute to increased generation of household income, ensuring food accessibility(Ainebyona, et al., 2012). The projected increase in the use of organic ingredients in food processing industries is likely going to contribute to the rise in amaranth production.

2.3.4 The potential of amaranth as an ingredient for food product development

Amaranth has great commercial potential as an ingredient in the food industry. The gluten-free flour, unlike that of wheat, forms a sustainable replacement of wheat in gluten-free products. At the household level amaranth can be used as a vegetable or the seeds ground to provide flour cooked and eaten as porridge (Mugalavai, 2013). Amaranth seeds can be malted to make beer, and the fatty acid-rich seeds can also be used to produce vegetable oil.

2.3.5 The Composition and Cultivation of Amaranth

As put byKauffman & Webber, (1990) amaranth is drought-resistant, water-efficient and can survive under high temperatures.The potential of benefiting from expanding cultivation and production of amaranth in Southern Africa is high (de la Rosa, et al., 2009). Compared to mainstream crops, amaranth requires 53–58 % less water than wheat and about 40–50 % less than maize (Kauffman & Webber, 1990).

2.4 Meat alternatives

Meat alternatives are classified as different protein sourcesconsumed in the place of meat. Their main aim is to supply a non-animal protein to the consumer but notessentiallymirrormeat for its nutritional and sensory properties (Smetana, et al., 2023).

2.4.1 Plant-based meat alternatives (PBMA)

PBMAs have increasedacceptanceworldwide due to their potential health and environmental benefits (Saxena, et al., 2021). They are typically made from plant proteins, such as legumes, grains, and vegetables, and aim to imitatemeat properties such as taste, texture and appearance (Bryant, et al., 2019).

PBMAs such as tempeh and tofuhave traditionally been consumed for centuriesalthough in most countries PBMAs are not so common. In recent times, factors such as the decrease in meat supply and the consequentialinstability of prices caused by the COVID-19 pandemicimpelledthe increase in demand and awareness of plant-based diets although they still compete relatively poor on the market as compared to animal meat (Kumar, et al., 2023).

The legumesoya bean is the most commonly used vegetable in the production of PBMAs. Soya bean is also used because of its accessibility, high nutrients and low cost of production. According toAndreani, et al., (2023), there have been rising concerns about soy cultivation, including biodiversity and increased awareness of genetically modified organisms (GMOs). This has prompted other pulse proteins such as other types of beans, peas, lentils, and chickpeas(Safdar, et al., 2022).

2.4.1.1 Production of plant-based meat alternatives (PBMA)

PBMAsare produced by four main steps, which are the selection of raw materials, the isolation of protein and processing. The main and common raw material for the production of PBMA regardless of the vegetable source, are compounds called “protein isolates”. Andreani, et al.(2023) state that to replicate meat in terms of colour, flavour, and succulence other ingredients of plant origin are required. The flavour profile of PBMAs is produced by using spices and herbs that are often used to mask the presence of off-flavours common with beans. Additionally, vegetable oils are often used toimitate other sensory qualities of meat. Binding agents, such as starches, are also essential to obtain a good meat-like structure. Lastly, after obtainingthe necessary ingredients, the most appropriate structuring procedure is selected (Lee, et al., 2023).

2.4.2 Consumer Perspectives on PBMA

Consumer perception is the main barrier to the production of plant-based meat alternatives despite modern technological innovation. Characteristics such as taste, price, and convenience, as well as indirect attributes such as health, sustainability and animal welfare are both drivers and barriers (Boukid & Gagaoua, 2022). Surveys have mainly been used to assess consumer attitudes towards PBMAs. These surveys revealed that the major influences for purchasing PBMAs are health consciousness and affordability. Since PBMAs are still considered new products, there is a need to raise awareness towards them to boost their performance in today's markets through education, interventions and innovation targeting production as well as cooking methods (Siddiqui, et al., 2023).

2.4.3. Feasibility of Plant-Based Meat Alternatives in School Meal Programs:

Several studies have shown the feasibility of incorporating plant-based meat alternatives into school meal programs. A study by Carvalho, et al., (2022) demonstrated the successful introduction of plant-based meat alternatives in school lunches, resulting in increased vegetable consumption among children. Another study by (Sogari, et al., 2022) found that children were willing to accept and consume plant-based meat alternatives when properly introduced and promoted.

2.4.4. Acceptability and Sensory Attributes of plant-based meat alternatives

The acceptability of plant-based meat alternatives among consumers, including children, is influenced by sensory attributes such as taste, texture, and appearance. Research by Falkeisen, et al., (2022) highlighted the importance of optimizing sensory attributes to enhance the acceptability of plant-based meat alternatives among children. A study by Plamada, et al., (2023) emphasized the need for sensory evaluation and consumer feedback to guide the development of plant-based meat alternatives.

2.5 Conceptual and theoretical frameworks

2.5.1 Conceptual Framework

The conceptual framework for this research project is based on the concept of food security, which is the availability and access to a sufficient, safe, and nutritious food supply. The development of a plant-based meat alternative using roundnuts and amaranth vegetable aims to contribute to food security in Zimbabwe by providing a sustainable and affordable source of protein for the country's school feeding program. The framework also emphasizes the importance of nutrition education, which can enhance the acceptance and consumption of the prototype product among school children.

2.5.2 Theoretical Framework:

The theoretical framework for this research project is based on the Diffusion of Innovations theory, which explains how new ideas or products are adopted by individuals or groups over time. The theory proposes that the adoption process involves five stages: knowledge, persuasion, decision, implementation, and confirmation. In this study, the prototype plant-based meat alternative made from roundnuts and amaranth vegetables represents the innovation, while the school children, teachers, and parents represent the adopters. This study aims to develop a product that will be easily accepted and adopted by the target population through effective communication and collaboration with stakeholders and the promotion of its benefits in terms of health, sustainability, and affordability.

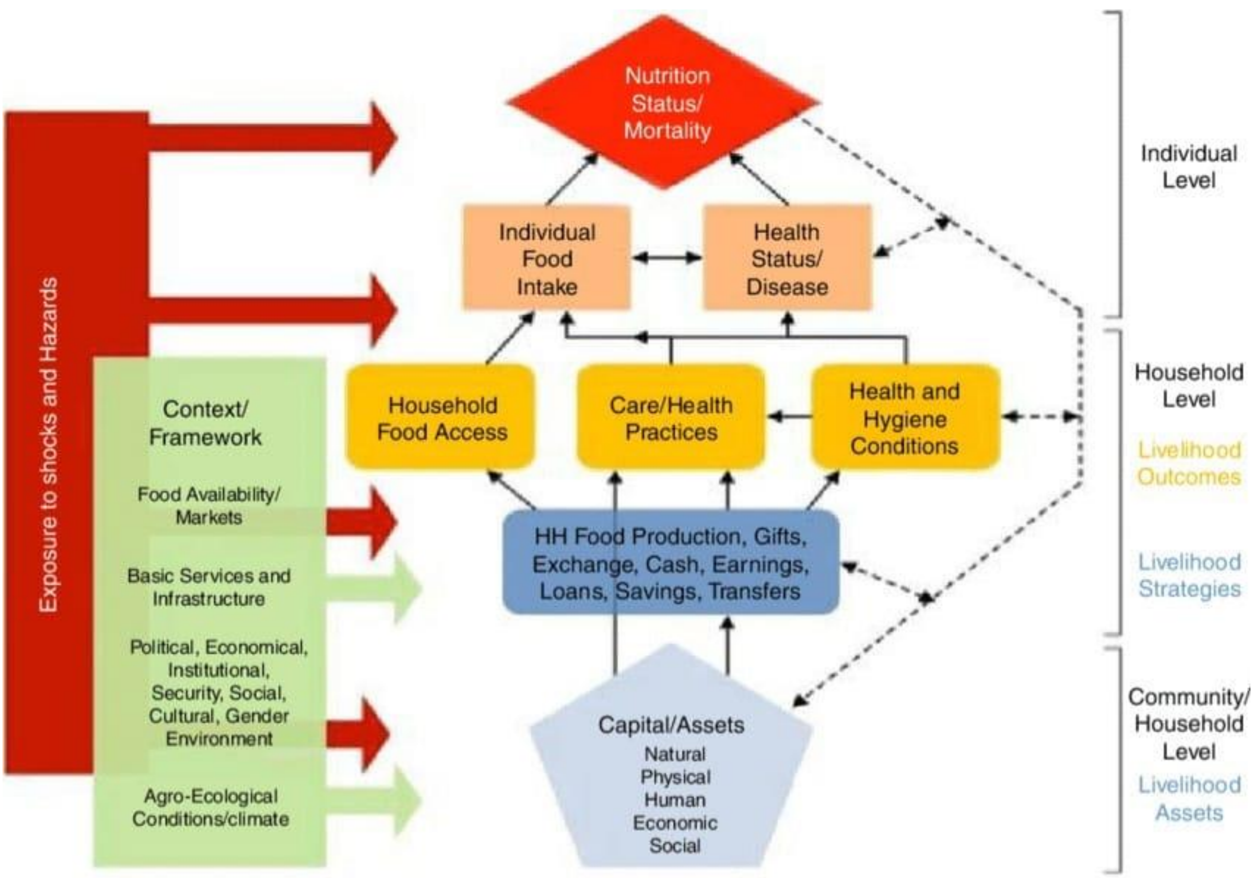

Figure 1: Food and Nutrition conceptual framework (Source: WFP, (2012) in Pokharel, (2016))

2.6 Summary

Both Bambara groundnut and amaranth vegetables are nutrient powerhouses which can be successfully used in food product development to create a wealth of nutritious foods. The legumes and vegetables are underutilised yet they provide a great solution for climate change adaptation and mitigation.

CHAPTER 3

MATERIALS AND METHODS

3.1 Introduction

This section delves into the research methodology utilized in this study, forming the foundational framework for the research. It encompasses details regarding the chosen study area, the sampling methodology, data collection techniques, presentation, and analysis. Additionally, ethical considerations and study limitations are elucidated

3.2 Brief Description of Study Area

The research was conducted in Harare Metropolitan, specifically focusing on the Epworth-Mabvuku district. Mabvuku, a high-density suburb located about 17 km east of Zimbabwe's capital, Harare, served as the primary study site. With an estimated population exceeding 30,000 (ZIMSTAT, 2012) Mabvuku provided a substantial context for the study**.**

3.2 Research Design

A mixed methods approach was employed in this study, combining qualitative and quantitative data collection and analysis techniques. This approach bolstered the research's accuracy and robustness by leveraging triangulation and cross-validation. It allowed for a comprehensive understanding of household food security among Mabvuku respondents, surpassing what either method could achieve individually. The primary data collection tools for quantitative data were laboratory experiments, sensory evaluation score sheets, and household survey questionnaires.

3.3 Sampling Procedure

The sample population included primary school children, teachers, and parents from the Epworth-Mabvuku district. Purposive sampling was utilized, with three schools namelyChinamano Primary School, Danckwertsi Primary School, and Tsinhirano Primary School selected by the Ministry of Primary and Tertiary Education. From each school, a random sample of participants was invited, ensuring a representative sample size of 30 based on statistical power analysis.

Inclusion criteria encompassed primary school children aged 6 to 13 years, along with teachers and parents responsible for meal preparation for the children, who consented to participate. Exclusion criteria included individuals with food allergies or intolerances to nuts or amaranth vegetables and those with specific dietary restrictions due to medical conditions.

3.4 Data Collection Methods

1) Laboratory Experiments: These experiments focused on optimizing the formulation and production process of a plant-based meat alternative prototype, gathering data on sensory attributes, nutritional composition, and shelf-life through scientific methods like chemical analysis and sensory evaluation.
2) Pilot Testing: The optimized prototype was tested in schools using a randomized controlled trial, collecting data on acceptability and consumption rates.
3) Surveys: Questionnaires were administered to assess attitudes, perceptions, preferences, demographic information, dietary habits, and food security status among participants.
4) Focus Group Discussions: Discussions were conducted with teachers and children from pilot testing to gather detailed feedback and identify potential issues or concerns.

3.5 Data Analysis Methods

1. Laboratory analysis and descriptive statistics were used to determine the proximate analysis of the Bambara groundnut and amaranth vegetable-based meat alternative.

2. Descriptive statistics such as means were used to determine sensory parameters of the Bambara groundnut and amaranth vegetable-based meat alternative and data visualization using charts, tables, and graphs were used to present results.

3. Inferential statistics (t-test, ANOVA, regression analysis) were used to assess consumer acceptability of the Bambara groundnut and amaranth vegetable-based meat alternative using an already existing meat substitute (soya chunks).

3.6 Ingredient Selection

The study utilized Mana and Kazuma varieties of Bambara groundnut due to their short-season availability and resistance to fusarium(Nafula, et al., 2021). These were sourced from the local MbareMusika market. Dried amaranth vegetable seeds and seasonings were obtained from local farmers and supermarkets, respectively.

3.7 Sample Preparation

1. Bambara groundnuts were ground to serve as the base for the meat alternative.

2. Amaranth vegetables were pureed to enhance the mixture's bulk and nutritional content.

3. Seasonings (salt, pepper, garlic) were added for flavour.

4. Binders (flaxseed meal) were included to bind the ingredients.

5. Vegetable oil was used for moisture and binding purposes.

3.7.1 Formulation of the meat substitute

Different formulation ratios used to blend the Bambara groundnut and amaranth are presented in Table 1 below.

Table 1:Formulation of the meat substitute

Formulation	% ratio (Bambara groundnut-amaranth)	QTY Bambara groundnut (g)	QTY amaranth
X	90-10	90	10
Y	80-20	80	20
Z	70-30	70	30

3.7.2 Standard recipe for cooking the meat substitute

Ingredients

For Cooking Meat substitute

i. 2 cups Meat substitute
ii. Water as needed to cook meat substitute

For Meat substitute relish

i. Meat substitute cooked
ii. 1 tomato, chopped
iii. 1One onion, chopped
iv. 1 teaspoon Salt to taste
v. 1 teaspoonRoyco powder
vi. Oil for frying

Instructions

Heat water in a saucepan. Bring this to a good rolling boil. Add in the meat substitute and switch off the flame. Cover with a tight-fitting lid and leave it aside for 15-20 minutes. Strain it in a colander and wash it with lots of cold water. Now squeeze the extra water with your hands. Squeeze to get as much water out of it. Set aside.

Heat oil and add meat substitute. Fry till golden brown on medium heat. Add onion, tomato and royco and simmer for 5 minutes. Add water to make sauce and simmer on low heat until thick and reduced

Notes

i. Once the meat substitute is cooked, strain and squeeze the extra water completely to remove the smell. Also, this prevents the mix from getting too moist when ground.

ii. You can add any spice mix that you prefer.

iii. Instead of Royco, you can use cornstarch.

3.8 Proximate analysis

3.8.1 Moisture Content Determination

Moisture content was determined by the oven-dry method as the loss in weight due to evaporation from the sample at a temperature of 105°C (Wrolstad, et al., 2005). A sample of 5g of the meat substitute was weighed into pre-weighed crucibles. The crucibles were placed in an oven at 105°C for one hour and thirty minutes. The samples were weighed periodically until there was no further change in the weight. The weight loss in each case represented the amount of moisture present in the sample. The moisture content was calculated using the formula below:

Moisture content = weight of original sample – the weight of the dried sample

The percentage moisture content was then calculated by dividing the moisture content by the weight of the original sample and multiplying by 100

$$\text{Moisture (\%)} = \frac{\textit{moisture content}}{\textit{weight of original sample}} \times 100\%$$

3.8.2 Fat analysis (Soxhlet extraction)

A sample of 20g of the dry samples wasweighed into the cellulose extraction thimbles. The thimble was plugged with glass wool and placed into a Soxhlet extractor. The initial weight of the empty flask in which the fat was to be extracted was recorded. The extraction was done by using the Soxhlet apparatus for six hours using petroleum ether as the solvent.Eighty millilitresof anhydrous ethyl ether was added into the ground glass flask which was attached to the extraction chamber and condenser. The flask was heated on a hot plate under gentle heat until a boiling action began and ether condensed and ran back into the extractor chamber.The flask was then removed from the apparatus, the petroleum ether was then evaporated by placing the flask in a water bath at 85˚C. The flask was then placed in an oven at 105˚C for 1 hour. The flask was then cooled, reweighed and the weight of the flask recorded. The percentage fat content was determined by subtracting the initial weight of the empty flask from the weight of the flask with fat; the difference was divided by the weight of the samples and multiplied by 100

3.8.3 Ash content

Ash content was determined by combusting the samples in a muffle furnace at 600^{o}C for 6 hours. A sample of 5g was weighed into porcelain crucibles that had been previously ignited and cooled before weighing The crucible and contents were ignited in a muffle furnace at 600^{o}C for 6hours until a greyish ash residue was produced The crucible was then reweighed to determine the ash content

3.8.4 Minerals

Mineral content was determined after ash content determination. The ash residue of each formulation was acid-digested, and mineral content was estimated by using an Atomic Absorption Spectrometer

3.8.5 Carbohydrate

The total carbohydrate content of the meat substitute samples was calculated by difference using the equations below:

$$Total\ \text{Carbohydrate}\ (\%) = 100 - (\%\ \text{moisture} + \%\ \text{protein} + \%\ \text{fat} + \%\ \text{ash})$$

3.9 Consumer acceptance of the meat substitute

The evaluation of the reception of the meat substitute was determined through sensory evaluation.

3.9.1 Pilot study

According to (Leon, et al., 2011)a ‘pilot study’ is necessary to determine the feasibility of an intervention on a larger scale.

Participants were enrolled from the three Primary schools. Voluntary participation was necessitated through the assistance of teachers. The pilot study resulted in changes in the sensory evaluation questionnaires as well as altering the processing method of the meat substitute by adding seasoning to the meat substitute so that it would be more acceptable to the students. In addition, the meat substitute samples were prepared as a relish prior to being evaluated.

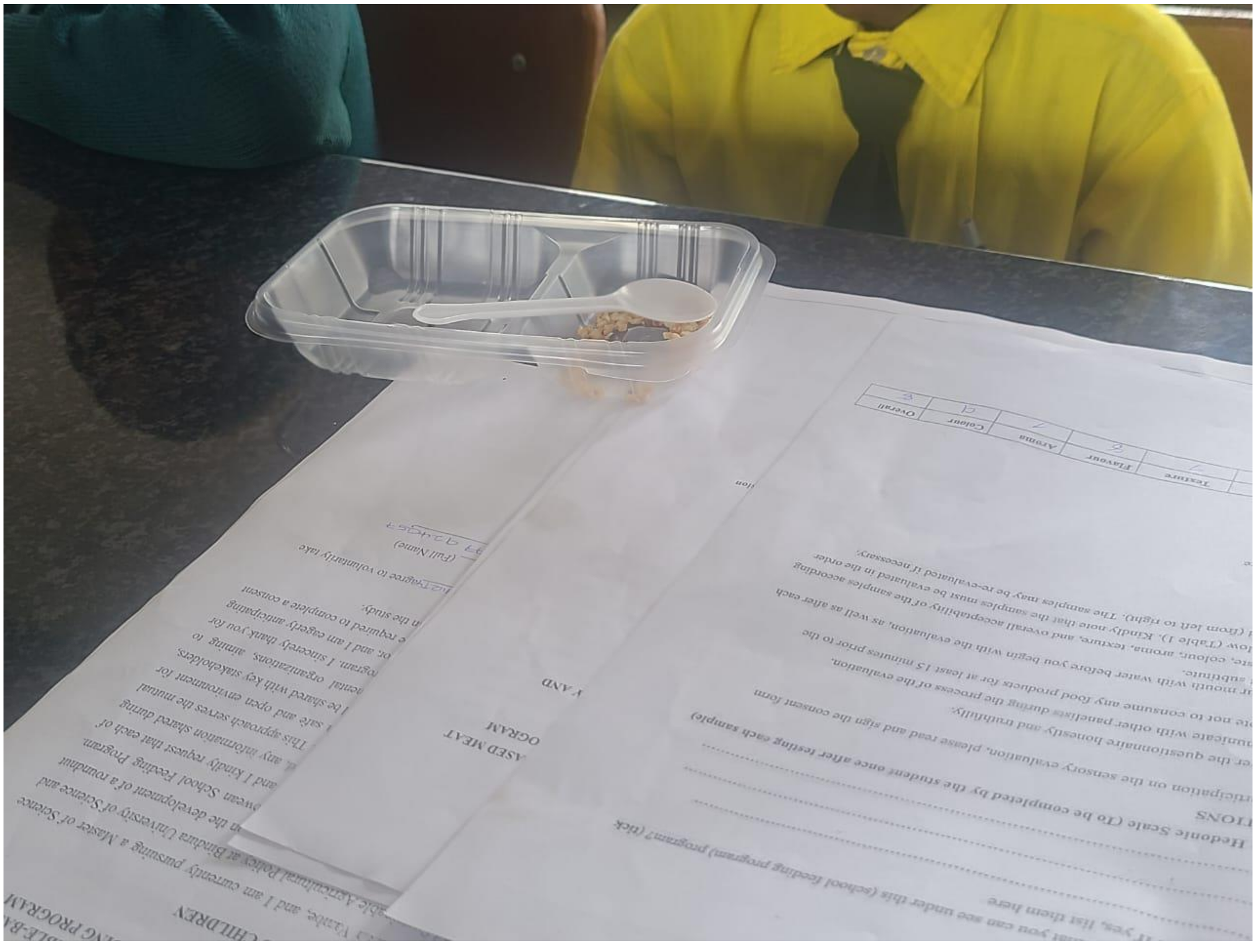

Figure 2: Scholar participating in sensory evaluation

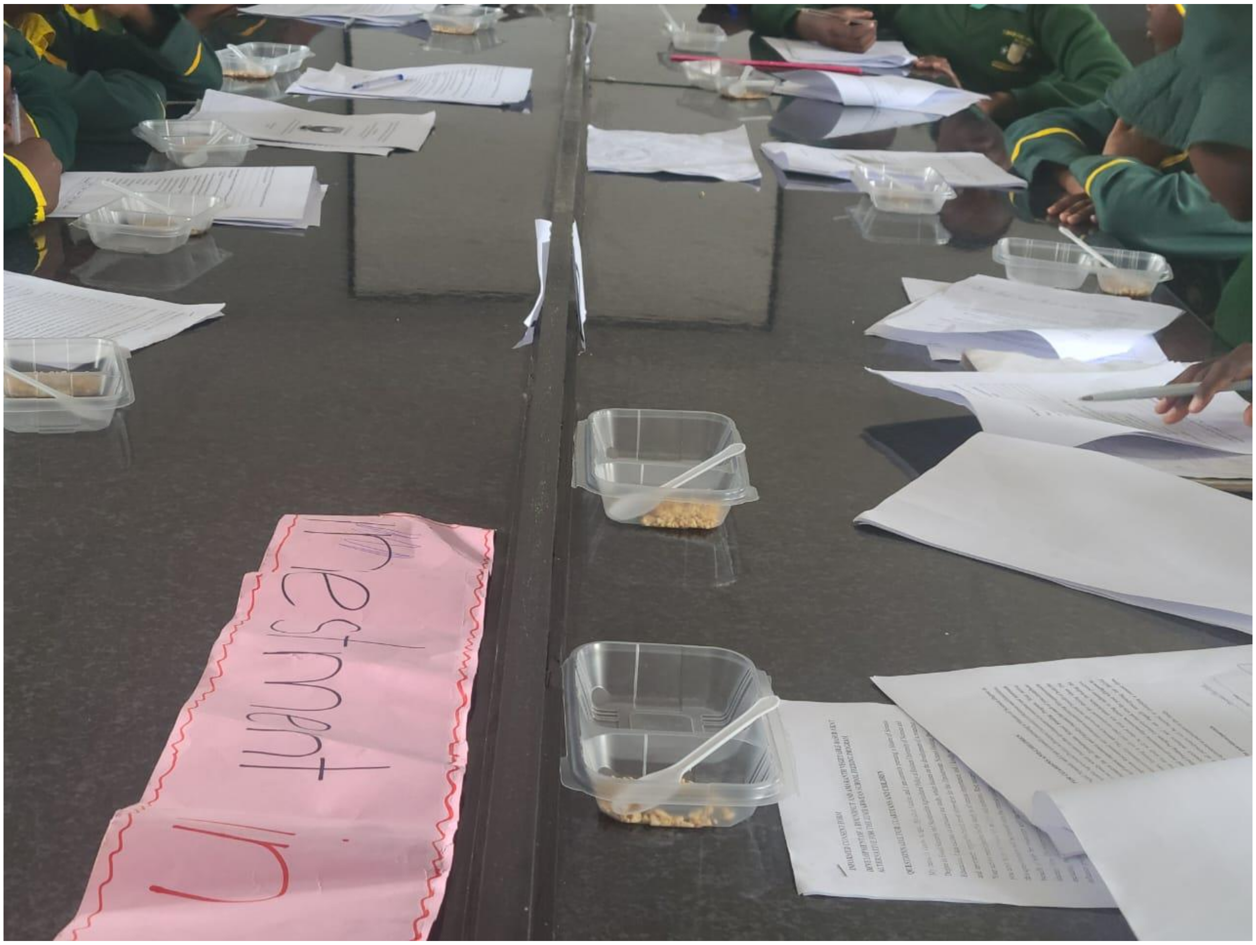

Figure 3: Scholars participating in sensory evaluation

3.9.2 The main sensory evaluation

3.9.2.1 Recruitment of panelists

According to (Stone & Side, 2004)50 or more subjects are required as minimum sample size to determine consumer acceptance. 180 parents on behalf of students as well as staff of Chinamano, Tsinhirano and Danckwertsi Primary schools who had provided consent and were regular participants in the school feeding program were recruited. Panelists were discouraged from eating any other food for at least 15 minutes before the evaluation.

3.9.2.2 Preparation of the meat substitutes

The meat substitutes were prepared by a standard recipe as described in section 3.4

3.9.2.3 The setup of the sensory evaluation exercise

All the panelists were provided with a questionnaire, meat substitute samples as well as water for rinsing the palate during testing. The sensory evaluation questionnaire had a 9-point hedonic scale with 1 being disliked extremely, and 9 being like extremely. (Bergara-Almeida, et al., 2003) state that the "hedonic scale" is a common instrument in food tasting to indicate the degree to which a food sample is liked or disliked.

3.9.2.4The setup of the sensory evaluation

Panelists were discouraged from communicating amongst themselves during testing so that they would not influence each other's responses. Before testing they had to sign consent forms (children under 18 had parents provide consent).The attributes of taste, texture, colour, as well as overall acceptance, were explained before the commencement of the sensory evaluation exercises.

3.9.2.5 Reduction of bias

The following steps were employed to avoid bias:

1. The sensory evaluation questionnaire used simple language.

2. Standard recipe for preparation of the meat substitute.

3.10 Ethical Considerations

1. Informed Consent: All participants, including parents on behalf of primary school children who are under 18 years of age and teachers, and parents, provided informed consent to contribute to the study. They were informed about the study and its purpose, and procedures as well as risks, benefits, confidentiality, privacy, and their right to withdraw at any time.

2. Confidentiality: All data collected from the participants was treated confidentially. The researcher used code numbers to protect the participants' anonymity. Data was stored securely and accessible only to authorized personnel.

3. Food Safety Standards: The prototype plant-based meat alternative adhered to food safety standards and regulations. The production process followed hygienic practices, and the product was tested for microbial and chemical contaminants before consumption.

5. Data Protection: The researcher took measures to protect the data collected during the study, including secure storage and destruction after the study's completion. The data was not shared with unauthorized persons or used for purposes beyond the study's scope.

3.11 Summary

The Ministry of Primary and Secondary Education provided a purposive sampling of schools. Local school teachers randomly selected students for participation. The meat substitute was formulated using three ratios. A standard recipe was developed to ensure consistency of results.

CHAPTER 4

RESULTS AND DISCUSSION

4.0 Introduction

This chapter presents the findings of the study to assess the development of an amaranth and Bambara groundnut meat substitute. The study made use of quantifiable and qualitative data collected through laboratory experiments, household surveys and semi-structured interviews. Results and discussion of key findings are presented in this chapter.

4.1 Response rate

A total of 108 questionnaires were distributed. Out of these, 99 questionnaires were successfully filled out and returned, resulting in a response rate of 91.7% which is adequate for conducting a comprehensive data analysis.

4.2 Demographic Profile of the Sample

The respondents' gender, age groups, education levels, occupations, and household income were recorded.Table 2 shows that the study has a relatively balanced representation of both male and female respondents. With 38% of the respondents being male and 62% being female, the study has managed to capture the perspectives of both genders. The slight dominance of female respondents may be attributed to the fact that more girls are enrolled in Primary schools in Zimbabwe (Ministry Of Primary And Secondary Education, 2021)and as in many African societies, women are primary caregivers or guardians of children under 18 years.

4.2.1 Gender

Table 2: Gender of the respondents

Group	Gender	Chinamano School	Tsinhirano school	Danckwertsi School
Students	Females	14	16	21
	Male	11	10	9
Parents	Females	20	18	11
	Male	5	18	9

Teachers	Females	3	4	4
	Male	3	2	2
Aggregate	Females	37	38	36
	Male	19	30	20

4.2.2 Age of respondents

Age distribution was relatively diverse, which ensured capturing the perspectives and experiences of individuals from different age groups. The highest proportion of respondents falls within the 10-13 years age range, who are the primary school children, the main target group of the research.

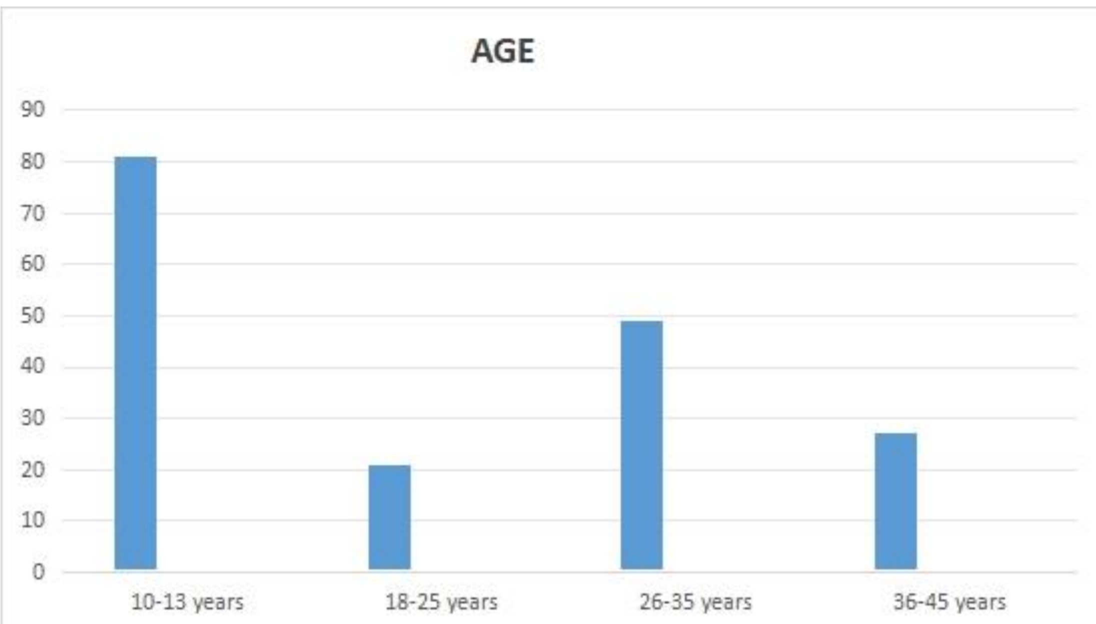

Figure 4: Respondents' age

4.2.3 Respondents level of education

The respondents had different levels of education, ensuring different perspectives. Again, the largest proportion of respondents were the primary school-going children, the main target group of the research. Respondents with no formal education as well as those who had only completed primary school ensured the inclusion of participants from more marginalized educational backgrounds. This allows the study to capture the perspectives and experiences of individuals who may have limited access to resources, information, skills and advanced academic qualifications as shown in Figure 5.

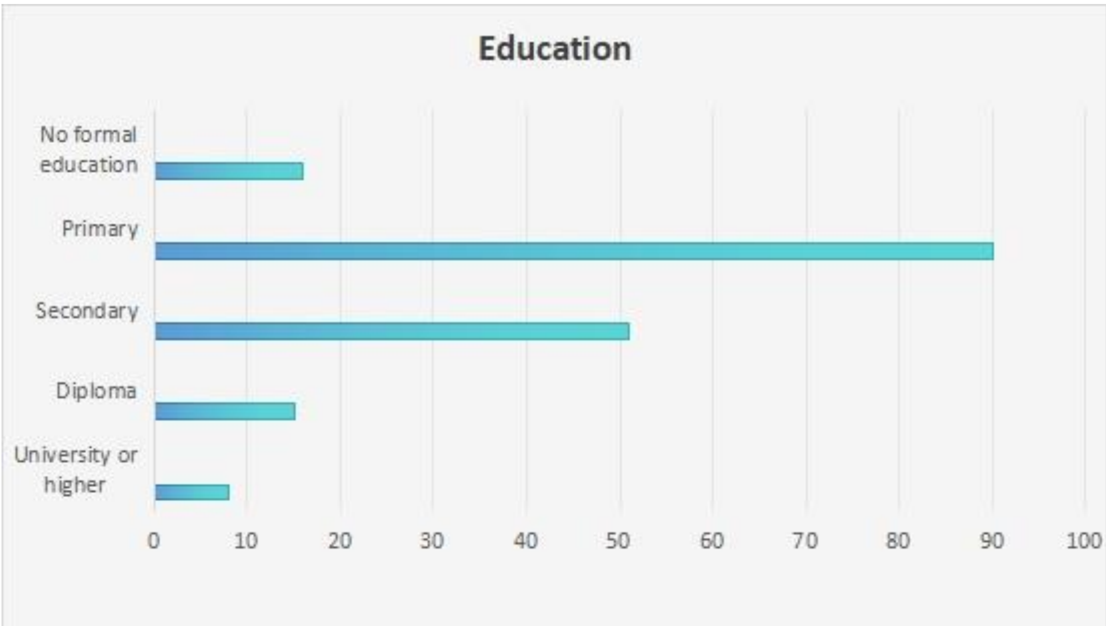

Figure 5: Respondents' level of education

4.3 Proximate analysis of the meat substitutes

The results of the proximate analysis are presented in Table 2. As shown by the results the higher the Bambara/amaranth ratio the lower the moisture content of the meat substitute. Formulation X which had a Bambara to amaranth ratio of 9:1 had the highest moisture content (at a 5% confidence level) of 10.75% while Z whose ratio of Bambara groundnut to amaranth was 7:3 had the least moisture content of 9.22% (at 5% confidence level). High moisture content in the 80%/20% Bambara and amaranth ratio is not favourable, as high moisture results in lower shelf life due to microbial outbreaks(Kabuo, et al., 2017).

Table 3: Proximate analysis of meat substitute formulation samples

PARAMETER	QUANTITY/100g		
	Sample X	**Sample Y**	**Sample Z**
Protein	22.7	25.9	28.63
Moisture	6.73	4.11	2.86
Carbohydrate	63.43	62.21	54.8
Fibre	2.72	3.37	8.13
Fats	1.56	1.98	2.12
Acid Insoluble Ash (wet digestion	2.86	2.33	3.46

4.3.1 Protein

It was observed that the protein content of the meat substitute increased as the ratio of amaranth and Bambara groundnut increased (at 5% confidence). Sample Z had the highest protein content. The findings are in line with results found by Ijarotimi & Keshinro(2013) who evaluated the nutrient composition of complementary foods formulated by blending corn and Bambara nut flour. Results also showed that protein content ranged from 22.7gto 28.63g. (Akinola, 2021) attributed this high protein content to Bambara groundnut as well as amaranth present in the meat substitute. According to (Arinola, et al., 2021) other studies have also described an increase in the protein of products as a result of formulating with legumes such as groundnut, Bambara groundnut, as well as soya bean into their formulation. This study therefore supports literature which states that legumes and amaranth are excellent plant protein sources. According to (Eckl, et al., 2011) protein content of meat substitutes should be comparable to or higher than traditional meat products, typically in the range of 15-25g of protein per 100g serving. Thus the high protein content confirms the suitability of the Bambara and amaranth blend as a meat substitute.

4.3.2 Carbohydrate

Results showed that carbohydrates in the meat substitute varied from 66.03 in formulation X to 54.8% in formulation sample Z. The carbohydrate content decreased significantly (p=0.05) as the ratio of substitution increased which was similar tothe results that were reported by (Okoye, et al., 2019)

4.3.3 Ash content

The meat substitute ash content ranged from sample X's2.86% to 3.46 % of sample Z. As the concentration of amaranth increased the ash content also increased significantly (5% confidence). The amount of ash in food indicates its mineral content (Nwajinka, et al., 2020). (Awolu, et al., 2015)) obtained similarly for a porridge blend consisting of sorghum and Bambara groundnut. Literature by (Awolu, et al., 2017) also predicted that amaranth greatly contributed to the meat substitute'sash content.

4.3.4 Fat content

The fat content of the meat substitute samples ranged from 1.56% in X to 2.12% in sample Z. There was a noteworthy increase in the meat substitute's fat content as the ratio of amaranth in the formulation increased. A similar trend was observed by (Sodipo, et al., 2021)).

4.3.5 Crude fibre

The meat substitute's crude fibre ranged from 0.12 to 8.13%. The researcher noted that the crude fibre of the Bambara nut meat substitute increased significantly (at a 5% confidence level) as the ratio formulation increased. This can be attributed to the relatively high fibre content of amaranth. Fibre has several nutritive benefits such as stimulating and accelerating intestinal contraction, adding to the volume of faecal matter, aiding digestion and preventing cancer(Lattimer & Haub, 2010).

4.3.6 Moisture

The meat substitute's moisture content fluctuated between 2.86 g and 6.73 g. According to (Bugusu, et al., 2001) the values are within the acceptable range for dried food which is less than or equal to 10 g per 100g of sample. These results indicate that the meat substitute has a stable shelf life.

4.3.7 Proximate analysis comparison with existing meat substitute (soya chunks)

The nutritional composition of the meat substitute was compared against an already existing meat substitute which is used in the Zimbabwe school feeding program, namely soya chunks. Results are shown in table 4.

Table 4: Proximate profiles of meat substitute and soya chunks

	Protein	**Carbohydrates**	**Fibre**	**Fat**	**Ash**	**Moisture**
Meat substitute	28.63	54.8	8.13	2.12	3.46	2.86
Soya chunks	41.8	31.4	12.6	8.3	4.2	1.7

Table 5:T-test of proximate comparison (Source SPSS Version 20)

	Test Value = 0.05					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
protein	5.340	1	.118	35.16500	-48.5054	118.8354
carbohydrate	3.679	1	.169	43.05000	-105.6126	191.7126
fibre	4.615	1	.136	10.31500	-18.0834	38.7134
fat	1.670	1	.343	5.16000	-34.1022	44.4222
ash	10.216	1	.062	3.78000	-.9213	8.4813

moisture	3.845	1	.162	2.23000	-5.1396	9.5996

The above analysis shows that there is no significant difference (at 5%) between the two meat substitutes' proximate values. Therefore the researcher can conclude that the Bambara groundnut and amaranth vegetable is a nutritious meat substitute.

4.4 Sensory Properties of Bambara nut-based meat substitute

Table 4 shows the sensory properties of colour, aroma, and acceptance of the meat substitute. The average sensory attribute scores were 6.50for colour, 6.95 for taste, 6.55 for aroma, 6.80 for texture and 6.95for overall–acceptance. Colour is an indicator of the quality of food materials and an indicator of formulation adequacy (Ogundele, et al., 2018).

Table 6: Sensory attribution of the meat substitutes

Attribute	Sample x	Sample Y	Sample Z
Taste	4.96 ± 2.50	4.93 ± 2.46	4.59 ± 2.53
Colour	5.00 ± 2.09	6.18 ± 2.13	6.95 ± 2.32
Aroma	5.00± 2.16	5.97 ± 2.26	6.55 ± 2.32
Texture	5.70 ± 2.40	6.00 ± 2.67	6.80 ± 2.5
Appearance	5.71 ± 2.51	6.64 ± 2.30	6.70 ± 2.29
Overal acceptability	5.30 ± 2.27	6.55 ± 2.27	6.95 ± 2.30

The colour score of the amaranth and Bambara meat substitutes ranged from 5 to 6.95. Sample Z had the highest score of 6.95. The differences in the colour scores were however not significant at a 5% confidence level. Sample X had the lowest score of 5.

Taste is defined as the "sensation of flavour perceived in the mouth and throat on contact with a food". It is a very important characteristic of food. Taste could be affected by factors such as ingredient quality and formulation of recipes(Small & Prescott, 2005). The mean scores of taste ranged between 5 for sample X and 6.95 for sample Z. This could be credited to the ratio addition of amaranth.

Aroma is described as a unique, usually pleasing smell perceived by the nose(Small & Prescott, 2005). The means of scores for the aroma of the blended meat substitute ranged from 5 in sample

X to 6.55in sample Z. The increase could be attributed to the pleasant smell of amaranth (Akinola, 2021).

The scores for flavour were highest in sample Z having a score of 6.55 and lowest in sample X at 5.85 although the scores were not significantly different (5% confidence). As the ratio of amaranth increased the favour profile of the meat substitute was improved.

The meat substitute samples had appearance scores which ranged from 5.7 to 6.8. Sample Z had the highest score as it also had the highest ratio of amaranth.

Overall acceptability refers to the general acceptance of the product concerning all the discriminating sensory attributes of the sample (Ogundele, et al., 2018).

The meat substitute's overall acceptability ranged between 5.3 and 6.95. Sample X had the lowest overall acceptability score of 5.3 which was significantly different from that of sample Z which was 6.95

Table 7:Panelists' rating of the three meat substitute samples

Scale	**Sample X**	**Sample Y**	**Sample Z**
Dislike extremely	11.4%	13.6%	9.1%
Dislike very much	20.7%	13.8%	20.7%
Dislike moderately	13.0%	8.7%	8.7%
Dislike slightly	27.0%	18.9%	16.2%
Neither like nor dislike	16.4%	11.5%	9.8%
Like slightly	20.0%	18.2%	12.7%
Like moderately	16.3%	23.3%	17.2%

Like very much	13.6%	13.6%	22.7%

Table 8: One-Sample T-test results for acceptance comparison

	Test Value = 0.05					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
taste	36.343	5	.000	5.22833	4.8585	5.5981
colour	23.960	5	.000	5.99500	5.3518	6.6382
aroma	17.135	5	.000	6.37333	5.4172	7.3295

The average scores for both colour and texture of the samples increased with an increase in the ratio of formulation, as well as the general acceptability.

These results are in line with findings by Mbata, et al., (2007) that there is no significant difference in mean scores of samples of a complementary porridge formulated with different Bambara groundnut ratios.

The results show that the meat substitute prepared with different ratios of Bambara groundnut and amaranth had a favourable response from targeted consumers. Both Bambara groundnut and amaranth vegetables contributed to the eat substitute's desirable sensory attributes. The roasting of the blends as well as the incorporation of amaranth into the formulation of the meat substitute could be attributed to the reduction in the "beany" off flavor of the legume.

4.4.3 Paired comparison of meat substitute and soya chunks

The results of the evaluation of the two meat substitutes (meat substitute and soya chunks) were analysed using SPSS. The researcher can be reasonably confident that the meat substitutes do not differ from one another, but there is still nearly a 5% chance of being wrong in reaching this conclusion. There is no significant difference in the acceptability of the two samples. The meat substitute can therefore stand competition with all other meat substitutes in the same category. The statistics prove that the product was therefore successfully developed.

Table 9:Scores for the paired comparison test

	Meat substitute	**Soya chunks**
Panelist 1	8	9
Panelist 2	6	8
Panelist 3	9	8
Panelist 4	7	10
Panelist 5	8	9
Panelist 6	9	7
Panelist 7	9	8
Panelist 8	6	8
Panelist 9	7	10
Panelist 10	8	8

Table 10: Comparison of meat substitute and soya chunks One-Sample Test

	Test Value = 0.05					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
meat substitute	20.864	9	.000	7.650	6.82	8.48
soya chunks	27.496	9	.000	8.450	7.75	9.15

There was no significant difference in the general acceptance of the meat substitute compared with existing soya chunks.

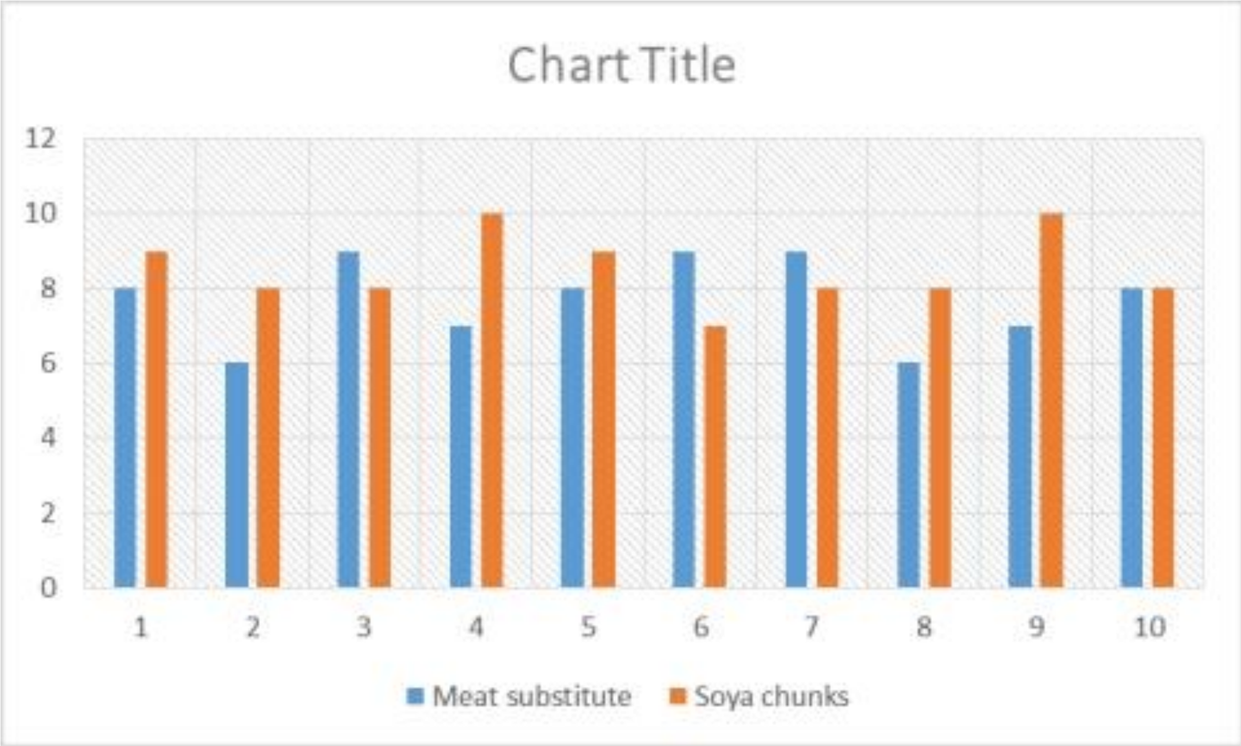

Figure 6:Paired comparison test

Conclusion

The development of Bambara nut and amaranth vegetable meat substitute using different ratios in the formulation was a success. The protein content of 28.63 makes the product suitable as a meat substitute and sensory evaluation proved the meat substitute was accepted by the target consumers.

CHAPTER 5

SUMMARY, CONCLUSION AND RECOMMENDATION

The research's main aim was to develop a meat substitute using the underutilized orphan crops namely Bambara groundnut and amaranth. The specific objectives were to: i). determine the proximate analysis of the roundnut and amaranth vegetable-based meat alternative; ii). Determine sensory parameters of the roundnut and amaranth vegetable-based meat alternative and iii). Assess consumer acceptability of the roundnut and amaranth vegetable-based meat alternative

5.1 Summary

The primary aim of this project was to develop a meat alternative based on Bambara groundnut and amaranth vegetables that meet the nutritional standards of the Zimbabwe School Feeding Program.

The objectives were to analyse the proximate composition and sensory attributes of the Bambara groundnut and amaranth vegetable-based meat alternative, as well as to assess consumer acceptability of the Bambara groundnut and amaranth vegetable-based meat alternative.

Bambara groundnuts and amaranth vegetables were milled, and blended in three different ratios of Bambara-Amaranth that is 9:1, 8:2 and 7:3. The blends underwent sensory evaluation to assess appearance, colour, texture, and overall acceptability. They were also analysed for protein, carbohydrate, fibre, and mineral content using standard methods. Consumer acceptability was tested through sensory evaluation by students and staff from three local schools in the Epworth-Mabvuku district.

The meat substitute's proximate qualities increased with a higher ratio of Bambara groundnut. Sensory evaluation revealed no significant difference at 5% confidence with regards to taste, colour, aroma, texture, appearance, and overall acceptability between the BGN-amaranth meat substitute and existing soya chunks.

5.2 Conclusions

The research proved that a legume-based meat substitute rich in nutrients such as protein, carbohydrates, fats and minerals can successfully be developed. The Bambara-amaranth meat substitute could significantly contribute to the nutrition requirements of Zimbabwe’s School feeding program, thus improving the general quality of the program. The study also made use of underutilized crops which are the Bambara groundnut and amaranth vegetable, which are both drought-resistant crops and therefore increasing their production can be a good climate change adaptation strategy.

The meat substitutes were also acceptable to the study sample with a similar or equal preference for the Bambara groundnut-amaranth meat substitutes as with the existing soya chunks in terms of sensory attributes of taste, colour, texture as well as aroma and general acceptance. As the ratio of incorporation of amaranth in the formulation increased, sensory attributes also improved. The colour of the meat substitute was also desirable.

5.3 Recommendations

5.3.1 Improving sensory attributes of the meat substitute as commended by sensory evaluation panelists

Texture

Extrusion factors such as temperature, the speed of extrusion screws and the water content of ingredients and final products all determine the quality of the meat substitute. Therefore it is recommended to use high-quality machinery for future research. The formulation can be adjusted to add starches fibres and gums to mimic the fibrous texture of traditional meat. Adjust the ratio of BGN-Amaranth to achieve the most desirable texture of the meat substitute

Flavor

Natural flavour enhancers such as herbs and spices to be incorporated in formulation. Other flavour compound such as yeast extracts and fermented products can also be added.

Appearance

The meat substitute's shape, size and colour can be adjusted to closely resemble that of meat or already existing meat substitutes like soya chunks. Include natural colorants or food-grade dyes in formulation to achieve the desired color and visual appeal.

Aroma

The use of natural ingredients such as onion powder, or herbs can enhance the aroma of the meat substitute.

Sensory Evaluation and Feedback

Regular sensory evaluation with trained panelists and target consumers should be conducted to collect feedback on the product's sensory attributes and identify areas of improvement. Continuous refining of the formulation and processing techniques is necessary until an optimal product is developed.

5.3.2 Recommendations for integrating the BGN-Amaranth meat substitute into the school feeding program:

1. Assessing the economic feasibility of production and distribution of the meat substitute in schools compared to the traditional protein sources such as soya chunks they are already using.

2. Stakeholder engagement. Government Ministries such as Ministry of Primary and Secondary Education, The Ministry of Health and Child Welfare, community leadership should be involved in the planning implementation process. There should be effective collaboration at all levels in order to address any concerns that may arise.

3. There is also need to engage input from experts such as Nutritionists and Food Scientists to fully enhance the nutrition profile of the meat substitute.

4. The meat substitute may be introduced gradually in small quantities for the students to adapt to the new product. There should be robust marketing and awareness to educate

parents, students and school administrators on the nutritional benefits of the meat substitute.

5. The meat substitute should be made affordable or easily accessible to schools as well as local communities through ways such as government subsidies and production and distribution at local level.

6. The involvement of students, parents and teachers in recipe development, tasting and marketing can foster acceptance and ownership.

7. There should be continuous monitoring and evaluation of the impact and implementation of the meat substitute in the school feeding program. Data to be collected and analysed includes but not limited to overall program success, student and schools participation and acceptance as well as any nutritional outcomes (engage Ministry of health local clinics).

8. Periodic reviews to adjust make any necessary adjustments based on feedback from stakeholders.

5.3.3 Recommendations for improvement of school feeding programs

Most respondents highlighted some areas of concern for the Zimbabwe school feeding programs and their recommendations are highlighted in table 11.

Table 11: Recommendations from the study participants

Issues raised	Recommendations
Lack of adequate shelter for students when they are having meals. Students commonly have meals outside, sitting directly on the ground	Communities to partner with schools and build appropriate shelters for dining so that students can have a clean environment when they are eating
Lack of adequate utensils such as plates and cups. Students have to take turns which is time-consuming and disrupts learning activities.	There is a need to acquire enough utensils to allow a smooth flow of the school feeding program.
Monotony of recipes. Most students complained that meals lack variety and	Cookout fairs can be hosted to encourage the program cooks to be creative in terms of recipe

therefore they don't look forward to them	development and the structuring of meals to attract more students to the program.
Budget constraints. Budget constraints are a major concern for the program. Most of the ingredients are donor-funded and therefore there is a risk of discontinuity if donors withdraw support.	The use of readily available or locally produced ingredients should be popularized. This research sought to address this concern.

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5.5Appendices

DEPARTMENT OF AGRICULTURAL ECONOMICS, EDUCATION & EXTENSION

Bag 1020 BINDURA, Zimbabwe
Tel: 263 - 71 - 6505
Cell :0782057303
Email : lmusemwa@gmail.com

BINDURA UNIVERSITY OF SCIENCE EDUCATION

Date 06 March 2024

Dear Sir Madam

REQUEST FOR PERMISSION TO COLLECT DATA FOR ACADEMIC RESEARCH PROJECT

PROJECT TITLE: DEVELOPMENT OF A ROUNDNUT AND AMARANTH VEGETABLE MEAT SUBSTITUTE FOR THE ZIMBABWE SCHOOL FEEDING PROGRAM

ACADEMIC SUPERVISOR: DR L. MUSEMWA

This letter serves to inform you that **Abigail Nyashah Vambe, Registration Number** B225246B is studying towards a Master of Science in Food Security and Sustainable Agriculture in the Department of Agricultural Economics, Education and Extension.

During her final year of study, she is supposed to do a research project in her area of specialisation.

Please assist in any possible way. Data collected will be used for academic purposes only and will not be published without your prior consent.

Thank you for your assistance.

Yours faithfully.

CHAIRPERSON
Department Of Agricultural Economics Education & Extension
Faculty Of Agriculture & Environmental Science
OFFICIAL

Dr. L Musemwa
CHAIRMAN - DEPARTMENT OF AGRICULTURAL ECONOMICS, EDUCATION AND EXTENSION

DEPARTMENT OF ENVIRONMENTA SCIENCE

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Appendix 1: Clearance letter

All communications should be addressed to
"The Secretary for Primary & Secondary Education
Telephone: 794895
Telegraphic address : "EDUCATION"

ZIMBABWE

Reference: C/426/3
Ministry of Primary and
Secondary Education
P.O Box CY 121
Causeway
HARARE

22 March 2024

Abigail N. Vambe
64 Eves Cresscent
Ashdown Park
Harare

RE: PERMISSION TO CARRY OUT A RESEARCH IN HARARE METROPOLITAN PROVINCVE:EPMAFARA DISTRICT: CHINAMANO,TSINHIRANO AND DANCKWERTSI PRIMARY SCHOOLS

Reference is made to your application to carry a research from the above mentioned district schools on the research title:

"DEVELOPMENT OF A ROUNDNUT AND AMARANTH VEGETABLE MEAT SUBSTITUTE FOR THE ZIMBABWE SCHOOL FEEDING PROGRAM"

Permission if hereby granted. However, you are required to liaise with the Provincial Education Director Harare Metropolitan, who is responsible for the schools which you want to involve in your research. You should ensure that your research work does not disrupt the normal operations of the schools. Where students are involved, parental consent is required.

You are also required to provide a copy of your final report to the Secretary for Primary and Secondary

M. Pedzisai **A/Deputy Director: Research,Innovation and Development**

For: **SECRETARY FOR PRIMARY AND SECONDARY EDUCATION**

SCHOOLS INSPECTOR
EPWORTH/MABVUKU/TAFARA DISTRICT
MIN. OF PRY & SECONDARY EDUCATION
22 MAR 2024
P.O. BOX CY 1343, CAUSEWAY

THE DIRECTOR
Ministry of Primary and Secondary Education
Strategic Policy Planning, Research & Statistics
22 MAR 2024
P.O. BOX CY 121, CAUSEWAY, HARARE
ZIMBABWE

MIN. OF PRY. & SEC. EDUCATION
DISCIPLINE SECTION
HARARE PROVINCE
22 MAR 2024
P.O. BOX CY 1343, CAUSEWAY
ZIM. TEL: 04-792671/7/798146

Appendix 2:Permission letter from Ministry

INFORMED CONSENT FORM

DEVELOPMENT OF A ROUNDNUT AND AMARANTH VEGETABLE-BASED MEAT ALTERNATIVE FOR THE ZIMBABWEAN SCHOOL FEEDING PROGRAM

(Parents/guardians to complete for children under 18)

My name is Vambe Abigail Nyashah Vambe, a student at Bindura University of Science and Education. I am excited to introduce my study, which focuses on the development of a roundnut and amaranth vegetable-based meat alternative for the Zimbabwean School Feeding Program. I kindly request your voluntary participation in this study, as your opinions and insights will be greatly appreciated. All the information that you will provide will be strictly confidential. The recommendations you will have will be shared with key stakeholders to influence positive change in the Zimbabwe School Feeding Program and other related fields. You are required to complete this consent form to ensure your voluntary participation and that you have fully understood all the information about this study. Before we proceed, all participants should complete a consent form, ensuring their understanding and agreement to participate.

Full name……………………………………. Age……………………….

I do hereby voluntarily agree to take part in this research project. I understand the purpose of this study I have been made aware of the fact that I can withdraw at any time, my participation will not cost me and all the information I give will be confidential. I hereby give my consent that I have no known allergies to groundnuts and amaranth.

Signed………………………………………. Date……………………………………..

Appendix 3 Informed consent form

QUESTIONNAIRES

My name is Vambe Abigail Nyashah Vambe, a student at Bindura University of Science Education. I introduce my study, which focuses on the development of a roundnut and amaranth vegetable-based meat alternative for the Zimbabwean School Feeding Program. I kindly request your voluntary participation in this study, as your opinions and insights will be greatly appreciated. All the information that you will provide will be strictly confidential. The recommendations you will have will be shared with key stakeholders to influence positive change in the Zimbabwe School Feeding Program and other related fields. You are required to complete this consent form to ensure your voluntary participation and that you have fully understood all the information about this study. Before we proceed, all participants should complete a consent form, ensuring their understanding and agreement to participate.

Section A for Parents/ guardians

1. Sex……………

2. Age…………….

3. Village………………… Ward……………………………….

4. Locality: Rural………………… Urban………………………… Peri-urban……………..

Ward………………………..division………………………district……………

5. Level of education of guardian/parent

None	Primary	Secondary	Tertiary

6. Do you have a child in a school feeding program? (**tick one**) 1= Yes 2=No

If yes, how many

are they? ....

9. How do you rate the quality of the school feeding program? **(tick one)**

1= poor… 2=average 3=more than average 4=excellent

10. In your opinion, do you think that the school feeding program contributed to the nutritional requirements of your child/ren in school?

1) Strongly agree

2) Agree

3) Not at all

4) Not sure

11. To what extent do you think school feeding program contributes to students' nutritional requirements

1) Extremely contributes

2) On average

3) Does not contribute

4) Not sure

14. Are there any problems that you can see under this program?

Explain………………………………………………………………………………………

…………………………………………………………………………………………………..

Section B: To be completed by the student with the assistance of the teacher or guardian

My name is Vambe Abigail Nyashah Vambe, a student at Bindura University of Science and Education. I am excited to introduce my study, which focuses on the development of a roundnut and amaranth vegetable-based meat alternative for the Zimbabwean School Feeding Program. I kindly request your voluntary participation in this study, as your opinions and insights will be greatly appreciated. All the information that you provide will be strictly confidential. The recommendations you will have will be shared with key stakeholders to influence positive change in the Zimbabwe School Feeding Program and other related fields. You are required to complete this consent form to ensure your voluntary participation and that you have fully understood all the information about this study. Before we proceed, all participants will be required to complete a consent form, ensuring their understanding and agreement to participate in the study.

School	**Sex**	**Age**	**Grade**	**Locality (Rural/urban/peri-urban**

1. do you know about the feeding program? Yes…/ no….

2. If your answer is yes, where does it come from?

....

3. Are you satisfied with the food quantity and quality? yes….

/no………

4. What type of foods do you eat before coming to school and at school? (Add source (from home=1 or school feeding programme=2) in front of the food item)

Before coming to schools	**Breakfast**	**Lunch**	**In between main meals**

5. Do you think getting food in school helps you? (Tick one) yes…/no….

6. If yes, how do you think it helps you?

…………………………………………………………………………

……………………………………………………………………………………………….

……………………………………………………………………………………………….

7. Do you think the program helps with your nutritional needs? yes…. /no….

8. Are there any problems with the school feeding program (yes…/no…. If yes, list them here
………………………………………………………………………………………

………………………………………………………………………………………………

………………………………………………………………………………………………

Section C: Hedonic Scale (To be completed by the student once after testing each sample)

INSTRUCTIONS

1. Please provide consent by signing the consent form before participating in sensory evaluation.

2. Please provide true information and honest opinions.

3. You are not to communicate with another panelist during the exercise.

4. Please do not eat for at least fifteen minutes before the evaluation.

5. Please rinse your mouth with water in between each tasting.

6. Rate the samples' taste, colour, aroma, texture and acceptance according to the scale below.

9 = Like extremely

8 = Like very much

7 = Like moderately

6 = Like slightly

5 = Neither like nor dislike

4 = Dislike slightly

3 = Dislike moderately

2 = Dislike very much

1 = Dislike extremely

	Taste	Texture	Flavour	Aroma	Colour	Overall
Meat substitute						

QUESTIONNAIRE FOR TEACHERS

My name is Vambe Abigail Nyashah Vambe, student at Bindura University of Science and Education. I am excited to introduce my study, which focuses on the development of a roundnut and amaranth vegetable-based meat alternative for the Zimbabwean School Feeding Program. I kindly request your voluntary participation in this study, as your opinions and insights will be greatly appreciated. All the information that you will provide will be strictly confidential. The recommendations you will have will be shared with key stakeholders to influence positive change in the Zimbabwe School Feeding Program and other related fields. You are required to complete this consent form to ensure your voluntary participation and that you have fully understood all the information about this study. Before we proceed, all participants should complete a consent form, ensuring their understanding and agreement to participate in the study.

SECTION A

School	Sex	Age	Level of education	Locality (Rural/urban/peri-urban

7. Do you know about the school feeding program …. Yes…/ no….

If yes, what are the foods served……………………………………………………

………………………………………………………………………………………………………

……………………………………………………………………………………………………….

8. Are food varieties for students changed regularly? **(tick one)** yes…./ no…

If yes provide the food timetable………………………………………………

9. How good is the feeding program poor…/average…/more than average…/excellent….

10. Does the program contribute to students' nutritional requirements?

i. Extremely contributes

ii. On average

iii. Not at all

iv. Not sure

11. Are there any problems with the school feeding program?

1=Yes 2=No

If yes, explain……………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

SECTION B

INSTRUCTIONS

1. Please provide consent by signing the consent form before participating in sensory evaluation.

2. Please provide true information and honest opinions.

3. You are not to communicate with another panelist during the exercise.

4. Please do not eat for at least fifteen minutes before the evaluation.

5. Use water provided to rinse your mouth during the tasting.

6. Rate the samples' taste, colour, aroma, texture and acceptance according to the scale below.

9 = Like extremely

8 = Like very much

7 = Like moderately

6 = Like slightly

5 = Neither like nor dislike

4 = Dislike slightly

3 = Dislike moderately

2 = Dislike very much

1 = Dislike extreme

	Taste	**Texture**	**Flavour**	**Aroma**	**Colour**	**Overall**
Meat substitute						

Appendix 4Questionnaires

QUESTIONNAIRE FOR HEDONIC SCALE

My name is Vambe Abigail Nyashah Vambe, student at Bindura University of Science and Education. I am excited to introduce my study, which focuses on the development of a roundnut and amaranth vegetable-based meat alternative for the Zimbabwean School Feeding Program. I kindly request your voluntary participation in this study, as your opinions and insights will be greatly appreciated. All the information that you will provide will be strictly confidential. The recommendations you will have will be shared with key stakeholders to influence positive change in the Zimbabwe School Feeding Program and other related fields. You are required to complete this consent form to ensure your voluntary participation and that you have fully understood all the information about this study. Before we proceed, all participants will be required to complete a consent form, ensuring their understanding and agreement to participate in the study.

INSTRUCTIONS

1. Please provide consent by signing the consent form before participating in sensory evaluation.

2. Please provide true information and honest opinions.

3. You are not to communicate with another panelist during the exercise.

4. Please do not eat for at least fifteen minutes before the evaluation.

5. Use water provided to rinse mouth during tasting

6. Rate the samples' taste, colour, aroma, texture and acceptance according to the scale below.

1 = Dislike extremely

2 = Dislike slightly

3 = Like very slightly

4 = Like much

5=Like extremely

	Taste	**Texture**	**Flavour**	**Aroma**	**Colour**	**Overall**
Meat substitute						

Appendix 5Sensory Evaluation Hedonic Scale

Key Informant interview guide

My name is Vambe Abigail Nyashah, a student at Bindura University of Science and Education. I am excited to introduce my study, which focuses on the development of a roundnut and amaranth vegetable-based meat alternative for the Zimbabwean School Feeding Program. Your active participation in this study is of utmost importance, and I kindly request that each of you contribute your valuable insights and opinions. Rest assured, any information shared during this questionnaire will be treated with the utmost confidentiality. This approach serves the mutual benefit of both the researcher and the respondents, fostering a safe and open environment for sharing ideas. The recommendations derived from this study will be shared with key stakeholders, including the government, policymakers, and non-governmental organizations, aiming to influence positive change in the Zimbabwean School Feeding Program. Please answer the questions below to the best of your knowledge.

1. What protein sources are consumed at your school for the school feeding program? *(Rank them according to the order of preference)*

a. *Investigate the reasons why the protein sources are consumed*

b. *Who consumes what protein sources?*

c. *What purposes do these protein sources play?*

2. Why do you think the younger generation is not interested in consuming traditional protein sources? a. *What could be done to encourage them to consume them?*

3. What do you regard as traditional protein sources?

4. What are your thoughts concerning processed meat substitutes? a. *Perceptions, Concerns and Beliefs*

Appendix 6 Key Informant Interview Guide