

**DEVELOPMENT OF NUTRIENT ENRICHED CASSAVA – ORANGE FLESHED
SWEET POTATO-BASED SNACK FOR SCHOOL FEEDING OF CHILDREN AGED
6-15 YEARS**

BY

ULANGO TOM

BSc. AGRIC (UMU UGANDA)

REG: 18/U/3035/MFN

**A DISSERTATION SUBMITTED TO THE INSTITUTE OF RESEARCH AND
GRADUATE STUDIES IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
OF THE MASTER OF SCIENCE IN FOOD SECURITY AND COMMUNITY
NUTRITION OF GULU UNIVERSITY**

DECEMBER, 2024

DECLARATION

DECLARATION

I, Ulungo Tom, do hereby declare that this Dissertation is my work and has not been submitted

to any institution for any Award

Sign: [Signature]

Date: 18/12/2024

APPROVAL

APPROVAL

This dissertation has been submitted for examination with our approval as supervisors

1. Professor Ipolito Okello-Uma

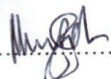
Professor, Department of Food Science and Postharvest Technology, Faculty of Agriculture
and Environment, Gulu University

Signature.....

Date.....

2. Dr. Muggaga Christopher (PhD)

Lecturer, Department of Food Science and Postharvest Technology, Faculty of Agriculture and
Environment, Gulu University

Signature.....

Date.....13/12/2024

DEDICATION

I dedicate this work to my wife Thorach Peace, children Jalocho Jonathan, Jamer Job, Nyarwoth Jasmin and my parents late Luke J. Utera and Lydia Utera.

ACKNOWLEDGEMENT

I would like to convey my appreciation for the assistance I received from my supervisors, Dr. Muggaga Christopher, Professor Ipolito Okello-Uma, and Dr. Nuwamanya Ephraim, for the lab work, not forgetting my friends Atibo Christopher, Oyet Sunday mark and Mvuranyi, Alangi, and Agyermach Primary Schools pupils, who deserve my sincere gratitude. I ask the Almighty God for the biggest blessings possible.

TABLE OF CONTENTS

DECLARATION	i
APPROVAL	ii
DEDICATION	iii
ACKNOWLEDGEMENT	iv
LIST OF TABLES	ix
LIST OF FIGURES	x
LIST OF ACRONYMS	xi
ABSTRACT	xiii
CHAPTER ONE	1
1.1 Background	1
1.2 Statement of the problem	2
1.3 Objectives of the Study	3
1.3.1 General Objective	3
1.3.2 Specific Objectives	3
1.4 Research Hypotheses	3
1.5 Conceptual Framework	4
1.6 Geographical scope	5
1.7 Study scope	5
1.8 Significance of the Study	6
CHAPTER TWO	7
LITERATURE REVIEW	7
2.1 Overview of Snacks	7
2.2 Causes of undernutrition	7
2.3 Status of undernutrition among school going children	8
2.4 Preference of prepared snacks among school children	14
2.5 Nutrient requirement for school-aged children	20

2.5 The use of starchy staples, cereals and legumes in development of snacks for children	29
2.6 Anti-nutritional factors.....	32
CHAPTER THREE	39
RESEARCH METHODOLOGY.....	39
3.1 Study design.....	39
3.2 Study area	39
3.3 Description of the population.....	40
3.4 Sample size estimation.....	41
3.5 Study Materials and Methods	41
3.5.1 Preparation of flours.....	42
3.5.2 Cassava flour preparation.....	42
3.5.3 Orange sweet potato flour preparation.....	43
3.5.4 Preparation of maize flours	44
3.5.5 Preparation of NAROBean2 flour.....	44
3.6 Formulation of the composites and snack development	45
3.7 Determination of Consumer Preference and Acceptability of the prepared snacks	49
3.8 Determination of proximate and micronutrient content of snacks.....	49
3.8.3 Crude fat.....	49
3.8.1 Crude Fiber	49
3.8.2 Crude Protein	50
3.8.4 Ash content	51
3.8.5 Moisture content	51
3.8.6 Energy content	52
3.8.7 Zinc and Iron.....	52
3.8.8 Vitamin A.....	52
3.9 Antinutritional elements include phytates, hydrogen cyanide, polyphenols, phenols, tannins and oxalates.	53

3.9.1 Oxalates.....	53
3.9.2 Tannins.....	54
3.9.3 Phenolic content.....	54
3.9.4 Hydrogen Cyanide	55
3.9.5 Phytates	56
3.9.1 Data analysis	56
3.9.2 Ethical considerations	56
3.9.3 Limitations of the study	57
CHAPTER FOUR: RESULTS	58
4.1 Sensory preference for cassava and OFSP-based snacks.....	58
4.1.1 Socio-demographic characteristics of study participants.....	58
4.2 Nutrient composition of cassava –OFSP based snacks.....	62
4.2.1 Proximate composition of cassava - OFSP -based snacks	63
4.2.2 Micronutrient content of cassava - OFSP based snacks	65
4.3 Anti-nutritional factors in Cassava – OFSP based snack formulations	67
CHAPTER FIVE	70
DISCUSSIONS.....	70
5.1 Sensory preference for cassava and OFSP-based snacks among primary school children	70
5.2 Proximate composition of cassava-OFSP based snacks	74
5.3 Micronutrient content.....	80
5.4 Antinutritional factors in cassava and OFSP-based snacks	83
CHAPTER SIX.....	88
CONCLUSION AND RECOMMENDATION.....	88
6.1 Conclusion	88
6.2.2 Recommendation	89
REFERENCES	91
APPENDIX 1: PLAGIARISM CHECK REPORT	107
APPENDIX 2: LETTER OF PERMISSION FROM CAO ZOMBO DISTRICT.....	108

APPENDIX 3: CONSUMER PREFERENCE AND ACCEPTABILITY DATA ENTRY FORM	109
APPENDIX 4: DATA COLLECTION SHEET ON SNACKS	110
APPENDIX 5. INFORMED CONSENT FORM FOR INDIVIDUAL INTERVIEW	111
APPENDIX 6: PHOTOGRAPH OF PLANT RAW MATERIALS AND FLOURS	114

LIST OF TABLES

Table 1: Daily nutrients included in school lunches consumed by students by region or school	21
Table 2: Recommended Dietary Intake for primary school-aged children.....	21
Table 3: The antinutritional factors in various food	38
Table 4: proportions of flours used in the development of snacks	46
Table 5: Additives used per 100g snack formulation	46
Table 6: Characteristics of the respondents	58
Table 7: Mean score of sensory characteristics segregated between formulations	60
Table 8: Overall preference of snacks	61
Table 9: Preference of the three best snacks according to age and sex	62
Table 10: Proximate composition of the most preferred cassava –OFSP based snacks Sensory	63
Table 11: p-value for macro and micro nutrients test results.....	65
Table 12: Mean micronutrients content of cassava-OFSP based snacks segregated by formulations	67
Table 13: Mean content of Antinutritional factors in the formulated snacks	68
Table 14: Test results on Antinutritional factors	68

LIST OF FIGURES

Figure 1: Conceptual Framework on micronutrient intake among primary school children.....	4
Figure 2: The map of Uganda showing West Nile Zombo district and research sub-.....	40
Counties source (Ulango Tom, 2023).....	40
Figure 3. Flow chart for preparation of snacks using cassava, OFSP, maize, amaranth and iron rich bean flours	47

LIST OF ACRONYMS

AM	Amaranth Flour
BMI	Body Mass Index
CAS	Cassava
Ca	Calcium
DRI	Dietary Reference Intake
Fe	Iron
GAE	Gallic Acid Equivalence
HQCF	High Quality Cassava Flour
IRB	Iron Rich Bean flour
IHR	Indonesian Health Research
IRBF	Iron Rich Bean Flour
LDPE	Low Density Polypropylene
MF	Maize Flour
NARO	National Agricultural Research Organization
OFSP	Orange Fleshed Sweet Potato
PEM	Protein Energy Malnutrition
RDA	Recommended Dietary Allowances
SFP	School feeding programme
SP1	(100% OFSP :0% CAS:0% MF: 0% AM :0% IRB)
SP2	(0% OFSP :100% CAS:0% MF: 0% AM :0% IRB)
SP3	(80% OFSP :5% CAS:0% MF: 7% AM :8% IRB)
SP4	(60% OFSP :10% CAS:10% MF: 7% AM :13% IRB)
SP5	(100% OFSP :0% CAS:0% MF: 0% AM :0% IRB)

SP6	(40% OFSP :15% CAS:20% MF: 7% AM :13% IRB)
SP7	(20% OFSP :20% CAS:30% MF: 7% AM :23% IRB)
SP8	(0% OFSP :25% CAS:40% MF: 7% AM :28% IRB)
SP9	(0% OFSP :0% CAS:55% MF: 7% AM :38 % IRB)
SSA	Sub-Saharan Africa
VAD	Vitamin "A" Deficiency
VHT	Village Health Team
WHO	World Health Organization
Zn	Zinc

ABSTRACT

Introduction

Undernutrition in rural regions is a global concern that is exacerbated by non-sustainable practices such as pupils feeding programs and school gardens. Nutrient-dense, reasonably priced meals can be given to rural populations as a solution. The goal of the current study is to develop a nutrient enriched snack made of cassava-OFSP blend that may be fed to school-age children (6-15 years) in the Zombo district. The snacks were formulated from a blend of cassava, Orange Fleshed Sweet Potato (OFSP), maize, amaranth seed and NARO Bean2 flours and contained both macro (protein, crude fiber, crude fats, ash, energy) and micro (iron, zinc and vitamin A) nutrients

Method

During the study, both a cross-sectional and a randomized design (CRD) were employed in the investigation. 130 pupils participated in the study and assessed the snack's preferences for colour, flavor, taste and mouth feel. Reducing the proportion of cassava and OFSP less than 25% and 0% respectively in the formulation, significantly ($p < 0.05$) improved the color of the snacks. According to the study, lowering these flour proportions could not have a significant ($p > 0.05$) impact on how good the snack tastes. Additionally, the taste and texture of the snacks SP3 and SP6 improved dramatically ($p < 0.05$) when the amount of cassava flour in the control snack SP2 (100% Cassava flour) was decreased. The study noted that adding other flours instead of cassava boosted the amount of protein in the new product SP5 (40% Orange Fleshed Sweet Potato, 15% Cassava, 20% Maize, 7% Amaranth and 18% Iron Rich Bean Flours) the control SP2 from 20.67% to 26.48% ($p < 0.05$). Similarly, addition of more flours to substitute cassava flour in snack SP2 significantly ($p > 0.05$) increased the crude fiber content from 0.8 in snack SP2 to 6.43% in snack SP3. The study therefore indicates that nutrient dense snacks can be developed using local plant materials that are available in the communities to meet the recommendable dietary requirement of iron 10mg/day for children 6-8 years, 8mg for boys and girls children 9-13 years, 11mg/day and 15mg per day for adolescent boys and girls and girls 14-18 years respectively among school children 6-15 years in Zombo district, West Nile Sub-region.

Results: The study developed 9 snack samples SP1 (100:0:0:0:0), control SP2 (0:100:0:0:0), P3 (80:5:0:7:8), SP4 (60:10:10:7:13), SP5(40:15:20:7:18), SP6 (20:20:30:7:23) SP7(0:25:40:7:28), SP8 (0:30:50:7:33) and SP9 (0:0:55:7:38) with various proportions (Orange Fleshed Sweet Potato: cassava: maize: amaranth seed: iron rich bean 2) flours respectively. Sensory analysis indicates that

variation in flour proportions resulted in the development of snacks that were significantly different ($p < 0.05$) by 0.84 score for colour compared to the control SP2. Flavour of the snacks improved by 0.61 score in snack SP3 while, mouth feel had a score difference of 0.83 for snack P6. Generally, flour formulation caused a significant ($p < 0.05$) change in snacks SP7, SP8 and SP9; for colour, SP3, SP4, SP5, SP6 and flavour SP8; SP3 and SP6 respectively but did not ($p > 0.05$) significantly improve taste and preferences of all the snacks despite SP3 score of 3.02 being the highest and lowest (2.79) in snack SP2 (control) using hedonic scale 5 liked most and 1 disliked most. Proximate and micronutrient analysis indicates that SP6, SP9 and SP3 had the highest iron (44.01mg/100g), Zinc (7.17mg/100g) and vitamin A (1441.33µg/100g) respectively however, SP3 had the highest (12.37%) moisture content making the snack prone to spoilage due to growth of microbes. Servings of snack (20g, 70g & 67g) of SP9, would meet 100% RDA of iron, zinc vitamin A for children 9-13 years, similarly, SP9 servings of 27.3g and 37.3g, 80g (girl) and 103g (boys), would meet 100% RDA of iron, zinc and vitamin A for children 6-15 years depending on the nutritional requirements for the various sexes and age of the children. The requirements of RDA of iron (10mg/day), zinc 5mg/day and vitamin A (400µg/RAE) per day for boy and girl children 6-8years respectively, while for boy and girl children 9-15years, SP9 and SP6 servings of (20g,70g,67g) and (18.2g,86.5g,57g) would provide the RDA of 5mg/day, 8mg/day 600µgRAE/day for iron, zinc and vitamin A respectively whereas, children 14-15 years would be served 103g and 85.6g of the snacks SP9 and SP6 to meet the RDA of vitamin A (900 µgRAE and 700 µgRAE) for boys and girls respectively and 153.4g serving and 190.3 g serving of SP9 and SP6 would provide 11mg/day for zinc.

Conclusion: The study indicates that locally available, nutritious and underexploited plant materials can be used to develop composite flour mixes using cassava, OFSP, maize, amaranth seed and NARoBean2 can be used to create edible and nutrient dense snacks that would meet the RDA for iron, zinc and vitamin recommended for education sector in Uganda to embrace cassava-OFSP-based snacks developed from the locally available foods in the current study with further studies on the effects of soaking, malting, roasting on the nutrient bioavailability.

Recommendation

Future studies should evaluate water soluble nutrients like iron, zinc and vitamin A bioavailability during the soaking, roasting, and malting processes used during the development of the cassava-OFSP snack formulations. Therefore, schools can develop snacks to enhance nutrient intake among the school children to improve their health and increase their concentration in class

Key words: Undernutrition, Micronutrients, Antinutritional factors, snacks

CHAPTER ONE

1.1 Background

Malnutrition significantly impacts cognitive development of children hereby affecting their academic performance in primary schools and starts among those under five years (Amoadu *et al.*, 2024). Studies conducted by Global Nutrition Report indicates that about 149 million children under five years were stunted, meanwhile 49.5 million were wasted and 40.1 million overweight (Abdoulaye *et al.*, 2018). Since these children under five years are undernourished, they end up joining primary schools when nutritional status is poor.

About 200 million school-aged children globally are stunted and underweight (Rahimi *et al.*, 2024) according to UNICEF, WHO & World Bank (2018), 54.83% of children were undernourished in East Africa while, 67% of adolescent children in Uganda (Asiki *et al.*, 2019). Similarly, studies indicate that 10.4% of the school children in West Nile are undernourished (Buzigo 2020). This could be due receiving lesser attention compared to their counterparts aged less than 5 years yet the children are in their preadolescent stage that demands adequate nutrients for growth and development as well training of in basic nutrition areas (Iyer & Siddhartha, 2024). More specifically, the cortical grey matter peaks up when a child is between 10 to 12 years of age (Chad & Lebel, 2024). This situation persists among children in rural areas when they join primary schools due to the low intake of nutritious foods that ends up affecting their growth and development (Global Nutrition Report, 2020). This has affected 920,000 Ugandan children who are undernourished despite the country having nutritious food options to enhance feeding in schools (UBOS & IYC, 2016). As such, malnutrition has been reported to have devastating effects on concentration and consequently on performance among the school children (Elolu & Ongeng, 2020). This challenge could be addressed through use of sustainable innovations such development of nutrient dense snacks that can be produced using locally available plant materials to reduce short term hunger and increase intake of nutrients such as iron, zin and vitamin A among primary school children especially in rural primary schools (Natabirwa *et al.*, 2020)

1.2 Statement of the problem

Studies indicate that about 42 million school children 6-15 years are malnourished in developing countries (Kwofi, 2021). The Uganda Demographic Health survey 2021 indicates that 8 % of the children under 5 years are wasted that is to say low weight for the recommended height while 38% are generally stunted (Maniragaba *et al.*, 2023). This condition makes children to join school while they are still malnourished and may be worsened due to feeding of primary school children mainly on starchy staples with low nutrient contents, resulting in 67% (920,00) Ugandan school children reported to be malnourished despite government interventions to reduce malnutrition (Asiki *et al.*, 2019) through School Feeding Program (UBOS & IYC, 2016). Increased vulnerable is due to insufficient intake of essential nutrients needed during this critical period of growth and development which can have long-term consequences for children's health, cognitive development and well-being (Chad & Lebel, 2024).

Most of the school children have poor nutritional intakes as they lack key nutrients such as iron, zinc and vitamin A, and therefore have to be compensated through supplementation using iron, zinc and vitamin A supplements yet these could be managed using homemade snacks that are nutritious (Adoko *et al.*, 2023). There is need to have effective strategies to manage and overcome malnutrition which is crucial among primary school children especially in the rural areas. For instance, in recent years, strategies such as school feeding programs have not been able to provide nutritious foods to improve school attendance and concentration in class (Wall *et al.*, 2022). There is lack of innovations to develop snacks using locally but nutrient dense food sources to meet the nutritional needs among rural school children (Fungo, 2023). One snack that has shown promise is the one made from Orange Fleshed Sweet Potato, Roba1 beans, maize and amaranth (Natabirwa *et al.*, 2020). These crops have high nutritional value, making them suitable for addressing malnutrition problems. In spite of that, there is still limited information on local bitter cassava variety *Nyarudota* – Orange Fleshed Sweet Potato (OFSP), National Agricultural Research Organisation Bean2 (NAROBAN2), amaranth seed and white and yellow maize based snacks. This study therefore, aimed at developing a nutrient-

enriched cassava and potato based snack as well as evaluating its acceptability, nutritional quality and anti-nutritional factors so that it can be incorporated into school feeding programs for children aged 6-15 years in primary schools to address the low food accessibility to food especially during periods of food shortages as most farmers depend on rain fed agriculture in Zombo District, West Nile Sub-region.

1.3 Objectives of the Study

1.3.1 General Objective

To develop a nutrient-enriched Cassava –OFSP based snack suitable and acceptable for school-feeding children 6-15 years in Zombo District.

1.3.2 Specific Objectives

1. To determine consumer preference and acceptability of Cassava and OFSP-based snacks.
2. To determine the Proximate and micronutrient Composition of cassava-based snacks
3. To determine the Anti-nutritional factors in Cassava –OFSP based snacks.

1.4 Research Hypotheses

Ho.1. Preference of the snacks shall not vary with variation in sensory attributes contributed by the various proportions of the flour used in snack development Ho. Ho.2. The combination of many different ingredients in the snack shall not affect the overall nutritional contents of the snack.

Ho.3 Formulation of snacks composite flours shall not increase the ant nutritional content of snacks

1.5 Conceptual Framework

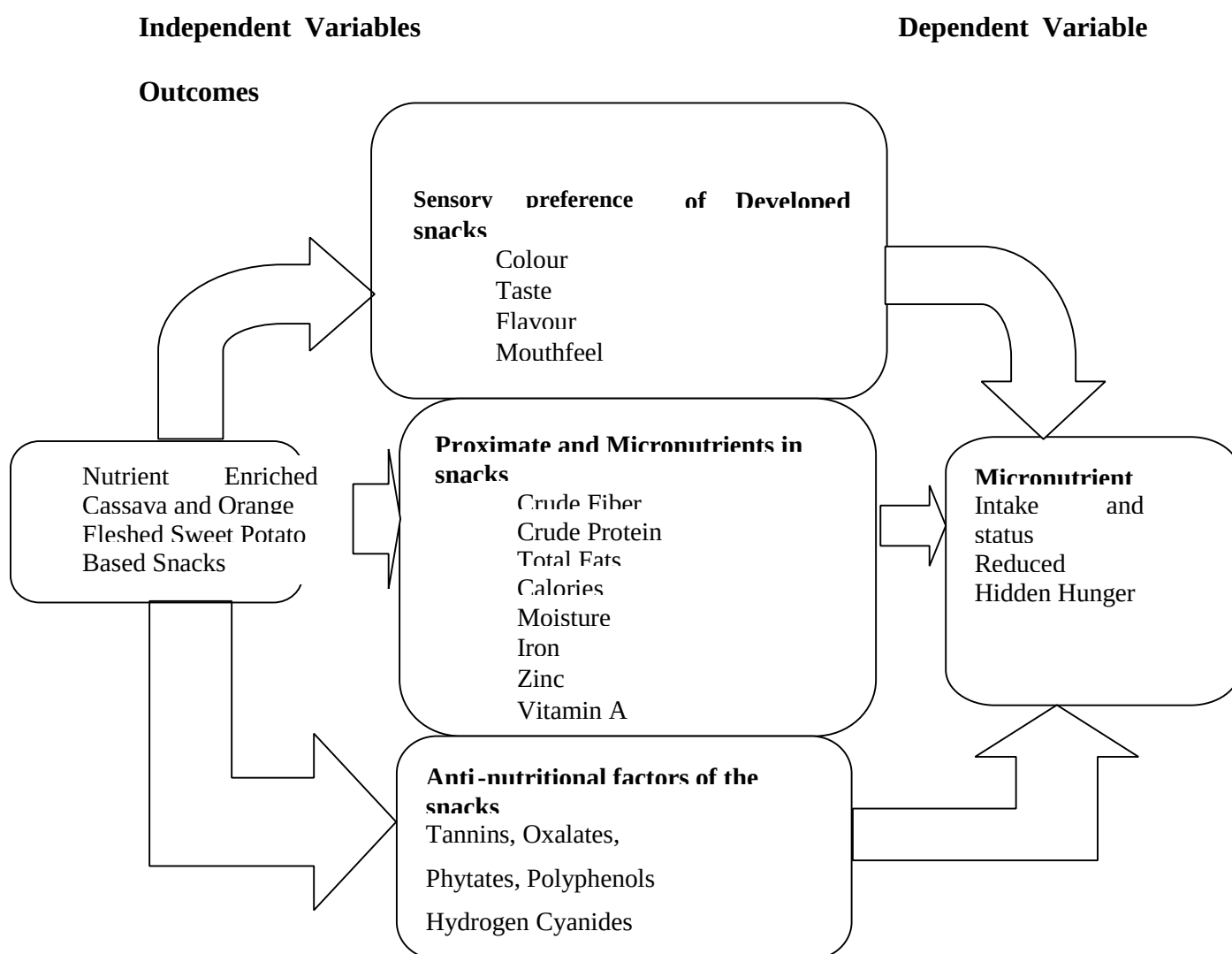


Figure 1: Conceptual Framework on micronutrient intake among primary school children.

Source: Ulango (Researcher (2023))

The conceptual framework in Figure 1 explains snack acceptability for school children 6-15 years in primary schools.

Nutrient intake among children 6–15 years is influenced by sensory properties such as taste, color, flavor and mouth feel which vary with flour proportions. Nutritional components in snacks also vary with processing and formulation of the flour proportions, these could affect the level of anti-nutritional factors and therefore nutrient availability (Chad & Lebel, 2024)

1.6 Geographical scope

According to Zombo district local government annual report 2021, primary school children in the rural areas are undernourished due to inadequate nutrient intakes, healthcare services that is worsened by lack of nutrition knowledge among women. The sub-counties of Warr and Alangi were selected in this study, targeting highly enrolled Government aided primary schools pupils of Mvuranyi, Pasai, and Agiermach with a total enrolment of 1,222 (613 girls and 609 boys), 1,513 (712 boys and 801 girls) and 1,364 (741 boys and 623 girls). These schools generally have poor performance among other schools in the district with exception of Agiermach primary school that has been able to produce a total of 4 pupils in first grade in the last 3 years. These schools hardly provide food during school hours with exception of some few pupils in upper primary as their parents can afford to pay for their meals under the schools arrangement. The schools were chosen since some of the pupils have their parents who are members of the Onyebu women group that grows quality declared IRON- Rich beans varieties and others who are not members of this group have access and capacity to obtain seeds from the group either through buying or local credit scheme supported by NARO.

1.7 Study scope

The current study developed snacks using 9 flour formulations using cassava flour known to have high level of calories but most importantly, local cassava variety known as Nyarudoda that was chosen due to the high preference to form bread that has high viscosity and lower hydrogen cyanide (HCN) (Oloya et al., 2018). OFSP variety, NASPOT12 and yellow maize Panner 38 procured in this study due to high level of carotene that would contribute to the reduction in vitamin A deficiency among school children (Haile & Getahun, 2020). Yellow maize was basically used to improve the sensory, nutritional and microbial properties of the snacks (Arisa *et al.*, 2021) whereas NARO Bean2 and amaranth seed flours were used as good sources of iron and zinc (Nafula, Ongeng & Alowo, 2021). The flours were formulated to provide a minimum of 25% RDA of the iron, zinc and vitamin

These snacks were tasted by the pupils for acceptability in the three schools of Mvuranyi, Pasai, and Agiermach to ensure that only the pupils are easily accessed to participate without interference from the communities around the respective schools.

1.8 Significance of the Study

Most of the children in rural areas are fed on mainly starchy foods that have low nutrients to keep them healthy, therefore, the developed snacks shall utilize the locally available nutritious but underutilized foods to increase accessibility to nutrient intakes such as iron, zinc and vitamin A among school children 6-15 years that would contribute to the recommended dietary requirements of the children especially rural schools compared to urban and boarding schools. This will foster better health, therefore increase enrolment and performance of the children in schools as a result of improved cognitive development and general academic progress of the pupils. Development of a snacks using several flours shall provide information that it is possible to develop snacks using locally available flours that have preference for the sensory properties such as colour, mouth feel high nutritional content and lower antinutritional instead of over depending on wheat to produce snacks to make snacks.

CHAPTER TWO

LITERATURE REVIEW

2.1 Overview of Snacks

Snacks are consumed between meals to satisfy hunger. However, they are primarily developed from cereals that are deficient in essential nutrients (Ndife et al., 2020). Snacks could be solid foods such as biscuits or liquids like porridge (Daba, 2021) and would play a pivotal role in improving nutrient intakes among children in primary schools since they appeal to young children (Dewidar & El, 2020). Other studies show that school canteen snacks typically contain low nutrient content of essential nutrients like iron level (Kwofi, 2021; Tsalissavrina, Murdiati & Raharjo, 2022). Therefore, using different types of flour in snack production has a potential to increase the nutritional content of processed foods by broadening the macro and micronutrient spectrum as some flours may be lacking the required nutrients (Green et al., 2019). For instance, previous studies have reported that snacks were made using flours from amaranth seed, maize, bitter cassava, NARO Bean 2 and orange-fleshed sweet potatoes (Sekiyama et al., 2015; Olapade, and Ogunade, 2014). Furthermore, cassava flour blends have also been used in making snacks for feeding children and have partially substituted wheat flour in snack recipes, as dough becomes more viscous with an increased water-to-flour ratio (Alamu et al., 2020; Natabirwa *et al.*, 2020). The current study therefore bridges the gap in developing easy-to-eat (ETE) healthy snack using cassava and OFSP options for schools status of undernutrition, a global concern that affects the health status of children globally.

2.2 Causes of undernutrition

Undernutrition (Hidden hunger) is a kind of malnutrition which occurs due to insufficient intake of micronutrients such as iron, zinc, vitamin A and calcium among others (Naicker & Singh, 2020). This condition affects individuals who have insufficient intakes of nutrients to meet the needs of the body for growth, maintenance and health (Miyingo ,Tukahirwa, Maniragaba , 2024). When the body does not get enough nutrients, it fails to function properly and can lead to deficiencies, immune functions,

general weakness, stunted growth and other health complicated issues as such in Uganda, it is estimated that 29% of children are generally stunted due to low intakes of nutrients (Sheffield *et al.*, 2024). Undernutrition could occur due to inadequate nutrient intakes, poor nutrient absorption or loss of nutrients due to increased rate of diseases such as diarrhea due to contaminated water sources commonly among the food insecure households (W. Anwar *et al.*, 2024). The current study is focused on micronutrient deficiencies (iron, zinc and vitamin A) which occurs commonly among rural children due to inadequate intakes of quality foods which are mainly starchy staples. This results into high morbidity coupled with poor feeding practices and socioeconomic status of many rural households. School children 6-15 years spend most of their time in schools that hardly provide sufficient food nutrients to meet their Recommended Dietary Allowances under school feeding program (Jeruszka-Bielak & Górnicka, 2024). Some of the parents pack poor quality foods that sometimes are left over that could expose the children to food poisoning, hence poor health yet these parents could process Easy To Eat (ETE) snacks in the rural communities using locally available plant based materials that would provide nutrients to the children sustainably since most parents fail to meet the nutritional requirement of the children throughout their years of studies especially during off crop seasons, Therefore, snacks developed is a hybrid approach to ensuring that children are provided quality foods such as using bio-fortified Orange Fleshed Sweet Potatoes variety NASPOT12 and NAROBan2 used in the current study to provide iron, zinc and vitamin A to reduce micronutrient deficiencies and reduce the rate of malnutrition and more specifically, undernutrition and therefore improve school attendance, enhance nutritional quality of the school feeding meals (Buzigi *et al.*, 2024).

2.3 Status of undernutrition among school going children

Globally, undernutrition can affect health status of children (Elolu & Ongeng, 2020), notably, according to Reggi *et al.*, (2024), 61.4 and 12.1 million children under five are stunted and wasted respectively in Africa as such, it impacts negatively on their cognitive development and therefore poor academic performance in primary school for example, studies in other African countries like Ethiopia, indicate that undernutrition among children was 2.74 times more common among school-aged children

aged 5 to 10 than it was in children aged 10 to 15 (Assemie *et al.*, 2020). Other studies in Uganda reveal similarly that undernutrition affects health status and academic performance of children in primary schools by weakening their immune system hereby increasing their susceptibility to diseases such as diarrhea. This makes children to miss lessons subsequently, resulting in poor performance (Asiki *et al.*, 2019), comparably, research from Indonesia indicates that 3–4 out of 10 teenagers suffer from anemia, with the prevalence of the condition being 32% (WHO, 2016).

When a child starts his or her academic progress while undernourished, the situation is likely to persist as the child grows up, yet these need a nutrient rich and healthy foods to enable them grow and develop well (Mohammed, 2022) . Therefore it was reported that 10.4% of school children in West Nile are undernourished which has negative implications on pupil's academic performance in primary school whereas another study emphasized that poor performance of the school children in rural primary schools have been linked to low nutritious food thus exposing them to nutrient deficiency risks (Achouri *et al.*, 2021).

Undernutrition in primary schools

Undernutrition affects cognitive and performance of school children in primary schools due to low intakes of essential nutrients such as zinc, iron and vitamin 'A' as they spend most of their time at school. Accordingly, Kiosia *et al.*, (2024) noted that less research is being undertaken concerning status of undernutrition among school children who consequently suffer from micronutrient deficiencies as a result of low intakes of micronutrients such as iron, zinc and vitamin A as noted in Ethiopia, particularly among primary school children who spend most of their time at school (Assemie *et al.*, 2020). This condition results in an imbalance of nutrients, leading to wasting, stuntedness, and underweight (Yisak *et al.*, 2022). Basically, rural schools often lack meals for these children, and parents often refuse to provide cooked food for school meals (Fungo, 2023). This leads to hunger and nutritional inadequacies, exposing them to health risks like iron anemia, which could lead to death. Similarly, some children in primary schools also suffer from parasitic infections, leading to diarrhea and wasting which can be certainly worsened by the mothers' low educational attainment (Anwar 2024) which lowers nutrient

bioavailability resulting in malnutrition and therefore poor growth and development among school children

School-Based Nutrition Programs

Provision of meals during school hours as one of the implementing strategies for school feeding, has the potential benefit of providing children with nutritious meals during the school day, however, these meals should be well-balanced in such a way that it offers adequate energy, proteins, vitamins, and minerals. This therefore calls for the use of locally and culturally appropriate foods that can be incorporated to ensure acceptance and sustainable school feeding of children for provision of not only energy, but also micronutrients such as Iron (Kwofie, 2021). Furthermore, supplementary feeding programs could be incorporated to reduce acute undernutrition when schools distribute fortified snacks or micronutrient dense food sources to children at risk to increase intake of required nutrients (Alcantara & Fronterras, 2024). Certainly, provision of fortified foods containing essential nutrients like vitamin A, zinc and iron, can help to combat micronutrient deficiencies among school children (Lowe, 2024)

Nutrition Education for Children, teachers and parents

The curriculum should integrate nutrition education in their teaching styles such as role play to help children understand the relevance of a balanced diet. This will improve the nutritional knowledge and self-efficacy when training on healthy eating habits using different food groups in the diets, and practical ways to ensure good nutrition is sustainably enhanced through processing of nutritious foods at household levels while knowing the values and sources of the required nutrients. This education needs to engage parents of the school children through provision of information materials that are pictorial and easier for the undedicated parents to promote healthy eating habits at household (Johnson, 2024).

Improving Access to Nutritious Foods

School garden establishment provides learning opportunities for children in growing nutritious foods and accessibility to fresh produce to supplement school. According to Afifah *et al.*, (2024), schools can collaborate with the local farmers and markets within the community to ensure a sustainable supply of fresh and affordable vegetables to enhance food diversification thus improve nutrient intakes due to increasing low food supply chain to that reduces the potentials of many households to meet the nutritional needs of the children and worsened by the effect of climate change.

Strategies to reduce undernutrition in primary schools

The current study is focusing on contributing to reduction of undernutrition among children aged 6-15 years in primary school. A Study has indicated that health status of school children deteriorates within this crucial age bracket (6-15) years since the demand for nutrients is higher at this stage for their growth, cognitive development, and overall well-being (Lipa, 2024). This being the most crucial stage, in that children need adequate nutrition to support their physical, mental development, emotions as well as their ability to focus and perform well in school (Murray *et al.*, 2024). Therefore, when these strategies are used, they could most likely help to address undernutrition among the primary school children.

WASH (Water, Sanitation, and Hygiene) Initiatives

Study indicates that poor quality water results in water contaminations due to E-coli. Hence need for primary schools to increase accessibility to clean and safe drinking throughout the year to prevent waterborne diseases that can accelerate malnutrition (Annanya Sardar, 2024). Additionally, there is need to introduce hygiene education in the teaching practices on the importance and how to effectively and regular hand wash. This therefore calls for the schools to have clean facilities that can promote hygiene (Sharma *et al.*, 2024).

Targeted Health and Nutritional Screening

Schools need to ensure that they routinely carry out nutritional assessments targeting undernutrition using parameters such as height, weight, and other nutritional indicators to identify children who are at risk for timely identification and interventions. Those children showing signs of severe undernutrition ought to be referred for further medical care and dietary support services using an organized referral system similar that conducted for older adults in USA during COVID 19 outbreak (Chaudhuri *et al.*, 2024).

Reducing household poverty

Undernutrition is associated to poverty due to the poor socioeconomic status of the households that reduce the ability of families to provide adequate nutrition for their children. Therefore, schools can play an advocacy role of collaborating with community organizations, governments, and NGOs to ensure that most food insecure families are supported with nutritious foods in case of increased insecurity (Sarmin *et al.*, 2024). A study by Vaiciurgis *et al.*, (2024) indicates that organizations could provide free or subsidized meals for the most vulnerable children since these households could be facing financial constraints to meet their nutritional needs. Additionally, schools need to involve children in daily activities like play and sports as this enhance their health and appetite (Buser *et al.*, 2024). This would as well provide a balanced physical and mental health holistically for a better being as this reduces stress while promoting healthy eating habits (Judijanto *et al.*, 2024)

Collaboration with Healthcare Providers

There is need for health check-ups and immunizations on regular basis that would include vaccinations, deworming, and micronutrient supplementation such as vitamin A and iron can be integrated into the school system. Most importantly, deworming can be particularly conducted to reduce the high risks associated with internal parasites to reduce malnutrition similar to that conducted in India (Chakrabarti *et al.*, 2024). This partnership could be enhanced between the schools and other Nutritionists and Dietitians in designing meal plans to meet the recommended dietary requirements for children through use of meals provided during school feeding programs.

Community and Government Support

The government of Uganda could establish policies to promote school meal programs, nutritional education as well as food fortification similar to that conducted in Ghana as reported earlier in Uganda (Nabuuma *et al.*, 2024). This is possible through public health campaigns to raise awareness about the relevance of child nutrition. The involvement of the local communities in efforts to improve children's nutrition can enhance collaborative approach especially using community leaders who can help in resource mobilization and awareness such as the effect of stunting among children in the communities (Fuadi, 2024).

Monitoring and Evaluation

There is need to establish a monitoring and evaluation system by carrying out regular data collection using Anthropometry to keep monitoring the nutritional status of school children in the schools to enhance effectiveness of interventions in combatting malnutrition status, so when conducted periodically, assessments can provide an insight into the success of nutrition programs and help in effective adjustments in the strategies depending on the identified and assessed need (Naisiae & Mungai, 2024).

Preference of snacks are indications of the adequate nutritional and energy contents of the snacks that could meet the dietary requirements of the targeted individuals (Natabirwa *et al.*, 2020). Normally, sensory characteristics of taste, mouthfeel, color and flavor are some of the most important factors in determining product acceptability in formulations made with maize, amaranth and OFSP flours, followed by aroma, texture and color (Elolu & Ongeng, 2020). Acceptability was reported to be higher in cassava due to its white color (Elolu & Ongeng, 2020). Additionally, germination and roasting processes used to prepare maize have an impact on the food items' overall appeal due to its sensory qualities such as flavour and improving on the bioavailability of the nutrients (Bello, 2018), therefore, processing of the grains into flour has the potential of improving on the physical, sensory and nutritional intakes due to reduced anti nutritional factors such as phytate

2.4 Preference of prepared snacks among school children

Preference of snacks is dependent on the sensory parameters of color, taste, mouthfeel and flavor which could vary among processed snacks.

Color of snacks

Studies conducted on the development of snacks in South Africa indicate that using various formulations of maize and baobab resulted in variations in the color of the snacks, hence affecting their acceptability (Netshishivhe *et al.*, 2019) . Another study found that roasting green chicken peas enhances the colour of snacks compared to browning due to milliard reaction during germination (Kumar *et al.*, 2020; Bork *et al.*, 2024; Schutte *et al.*, 2024).

Similarly, Dewidar & El, (2020) suggested that adding more products of Brocken White Bean Flour (BWBF) enhanced the color of snacks when mixed with corn flour. This is significant ($p < 0.05$) since color is one of the key factors in a food product's acceptance score (Oduro-obeng & Plahar, 2017). This happens when other flours such as OFSP have improved color of the snacks and therefore, their overall preference as conducted in other studies (Adoko *et al.*, 2021). In contrast, other studies noted that color did not significantly affect acceptability of snacks (Folorunso & Ojo, 2021; Badiu & Babawande, 2020). However, color of snack formulations have been shown to vary with variation in the proportions of the ingredients used such as dark colour due to increased proportion of OFSP flour (Alam & Islam, 2016). For instance, previous studies indicate that formulations of snacks using 20% soy flour and 40% chicken pea flour produced snacks with the most preferred colour, followed by snacks produced using 15% soy and 15% chicken flour meanwhile the lowest was without formulation using chicken pea and soy flour but used only guar gum flour (Shah *et al.*, 2017). According to the studies conducted by Damilola *et al.*, (2024) the most preferred samples was with increased OFSP content despite chewiness, gumminess, and cohesiveness meanwhile those with increased proportion of sorghum were liked for adhesiveness therefore, samples containing 80% and 90% sorghum received the highest overall acceptance 7.15 and 7.18, respectively.

Other foods formulation containing 20% banana and soybean flour were the best for older children, according to another study on the development of complementary foods for school children. However, biscuit color preference, there was no significant ($P > 0.05$) difference among the snacks when the products contained $\leq 50\%$ maize flour (Aderoju et al., 2020). Whereas, Ezekiel *et al.*, (2022) noted that incorporation of $\leq 20\%$ defatted baobab improved the sensory properties of composite flour. Therefore, using various flour proportions improve on the color appeal of composite snacks compared to when one type of flour is used hence improving on the overall acceptability this is due to the various colors of the individual flours when mixed can alter the natural color of the snacks, either by lightening or darkening depending on the proportions used (Elolu & Ongeng, 2020).

Taste of snacks

According to Jesulagba *et al.*, (2024), taste preferences for products improved with addition of more flours in the composite products. Furthermore, study indicates that use of 60 grams wheat and 40 grams cassava flours resulted into liked taste of the food product with preference value of 3.78 indicating that the taste was liked (Susanto & Hartati, 2024)

Additionally, it was observed that frying potato improves taste and preference of products (Anwar *et al.*, 2024). However, additional tests reveal that there was no discernible ($p > 0.05$) difference in the flavor, fragrance, or crunchiness of biscuits prepared with 100% cassava flour compared to those made with high-quality protein maize and yellow-fleshed cassava (Aderoju et al., 2020). Furthermore, because of their sour flavor, produced flour composites with a larger amount of cassava flour were rejected (Sanya *et al.*, 2020; Sahé *et al.*, 2019). Apart from this, preference for taste of amaranth seed, OFSP, maize and IRB snack blends varied significantly with flour proportions for school feeding of children due to their different proportions (Natabirwa et al., 2018).

In Ethiopia, a study was conducted on nutritionally enhanced instant porridge flour developed using 50% maize flour, 35% OFSP flour, 10% sweet lupine flour, and 5% Maringa leaf powder blends resulted into instant porridge with increased acceptability for all the attributes desired by the targeted children (Nega et al., 2024)

Flavour of snacks

As far as flavor is concerned, this is crucial in assessing the nutritional value of snacks (Gómez-Gaete *et al.*, 2024). Notably, an increased proportion of maize flour in the composite reduced the overall flavour, contrary to the effect of pea in studies conducted by other researchers (Fikiru *et al.*, 2016) therefore, variation in flavour with proportions of flours used to develop snacks using amaranth seed, OFSP, maize, and IRB for school feeding, as flavor improved the acceptability of snacks. It has been found that fermentation of lima beans increased flavor of beans; this takes place as a result of an increased PH resulting into photolytic enzymes' break down of proteins and releasing ammonia, hence affecting the flavor of food products. Ezekiel *et al.*, (2022), indicated that flavour of the flours improved by when composite flour was developed using 30% maize, 40% cassava and 30% sorghum. There was also an improvement with higher proportion of OFSP than those with a lower proportion of the flour in snack blends due to the effect of the carotene in OFSP (Nkanga & Inyang, 2024). Furthermore, Nkanga & Inyang, (2024) discussed that addition of more bean flour proportions increased preference and acceptability score of snacks and sensory evaluators rating them moderately for appearance, flavor, and overall acceptability, while yellow maize flour received the highest scores (Palupi *et al.*, 2024). Despite being a nutritious cereal crop, amaranth seed flour proportion in snack development and other composite flours should not exceed 50% due to the bitter after taste's characteristic and unappealing nutty flavor. The crop has a high nutritional value and contains bioactive substances that can be utilized to feed kids in elementary schools instead of animal protein

Other studies indicate that chin-chin a deep fried blends of cassava flour and snacks other ingredients more preferred flavor compared with snacks made using wheat chin-chin (Alamu, Maziya-dixon, & Olaniyan, 2020). This reduces with increased fat content due to the formation of peroxide during fat oxidation as such there is need to have a balanced and flavorful snack, by ensuring that cassava flour is used in moderation so that other ingredients with more distinct flavors like OFSP or beans to dominates flavour of the snacks hence increased preference scores this therefore alter the flavour of snacks by producing off flavours

Mouthfeel

Formulation of several flours can alter mouthfeel and evidenced in the development of biscuits whose fine texture decreased with addition of 20% extracted soy protein in developed biscuits using cassava, extracted soy protein, and pumpkin powder. Studies show that acceptability of snacks was highest with formulation using 5% of the extracted soy protein proportion due to the improved fineness texture (Aly & Seleem, 2015).

Other studies also indicate that formulation of beans and carob fruit flour improved the textural quality of snacks and therefore, enhanced the overall acceptability (Arribas *et al.*, 2019). Studies show that $\geq$ 50% proportion of maize flour improved the overall acceptability of the biscuit snacks (Aderoju *et al.*, 2020) basically due to reduced moisture content hence improved crunchiness and therefore acceptability of snacks. High energy and mineral density of the finished porridge resulted from the beans' optimal processing and incorporation with grain amaranth and rice flours improved acceptability for the porridge for the flour formulation using 40% bean, 30% amaranth, and 30% rice flour, respectively (Ndagire *et al.*, 2015).

Other studies conducted in Nigeria, indicate that while cookies developed using 100% wheat were preferred in addition, when the wheat proportion had a 5% substitution using unripe bananas and 5% pigeon pea, resulted in the development of the most preferred cookies (Adejumo *et al.*, 2020). The study in Uganda suggests that the increased hardness in the mouth may be due to the addition of amaranth seed flour (Wandeka *et al.*, 2022). Whereas other studies indicate that using 80% maize flour and 20% cassava flour produced biscuits that were more preferred and had the highest levels of macro and micronutrients due to attributes of complementary nutritional profiles as the two ingredient functional properties maize that could have contributed to the light and crispy texture while chewiness properties was added by the cassava all of which contributed to the preferred mouthfeel (Aderoju *et al.*, 2020).

According to another study conducted on snack formulation, it was reported that the formulation of snacks using 15 grams of soy and 15 grams of chicken pea per 100 grams produced the most acceptable snack in the study (Shah *et al.*, 2017). However, other earlier research suggests that the best snacking

amounts came from combining 84.75 g of quick maize meal, 5.25 g of Baobab Fruit Powder (BFP) and 10 g of Commercial Starch (CS) in the flour composition. (Netshishivhe et al., 2019).

Other studies showed specific requirements are satisfied when a mixture of 80% cassava starch and 20% soy flour was the most preferred deeper, golden color that had more protein (Millar *et al.*, 2017). Preferences usually vary among consumers who prefer 50% cassava flour and 20% soy porridge formulations, yet others prefer 50% cassava flour and 20% soy porridge (Daba, 2021).

Therefore, variation of flour proportions in snacks can provides us some opportunities to enhance flavor, texture, and therefore create more nutritionally balanced snacks Formulation of snacks using flour blends not only allow help in meeting diverse pupils demand and likely come up with products that are preferred and enjoyed.

2.5 Proximate Composition and Mineral Estimation of various snack formulations

The term "proximate composition" describes the proportions of various elements including moisture, fiber, and ash, together with macronutrients like proteins, lipids and carbs (Chikpah et al., 2020). These can be obtained in raw foods that have to be processed to make the foods more nutritious to enhance feeding among school-going children in primary schools. It has been noted that foods provided at school are of low nutritional content to meet the recommended dietary allowances of the school children while at school (Ismail et al., 2020). This has caused most of the children to have low intakes of macronutrients such as proteins, fiber, fats, energy and carbohydrates, resulting in malnutrition that is in most cases acute if not well managed earlier (Abdoulaye et al., 2018). Similarly, Damndja *et al.*, (2024) used yellow maize, cashews, and baobab pulp in which the maize was malted and cooked while cashew almonds roasted and cooked and baobab pulp was not exposed to treatment. These formulated flours provided, macronutrients, vitamins, and energy values however, concerning minerals, iron (5.12–5.30 mg/100 g DM) and calcium (141.02–181.94 mg/100 g DM) contents were lower compared to level recommended by WHO.

Processing snacks has an effect on the nutritional contents and is one of the strategies to increase consumption of macro and micronutrients (Nkundabombi, Nakimbugwe and Muyonga 2015). Some of

the processes, like malting, have been reported to improve food components through hydrolysis into easier-to-use ones (Haile and Shufa, 2019). According to Samtiya *et al.*, (2021), a combination of both germination followed by fermentation increased the level of zinc and iron, this was by 40.87% and 57% compared to germination only which had an increase by 28.04 and 22.31 for zinc and iron respectively (Samtiya *et al.*, 2021). Most importantly, processing methods can reduce food's nutritional value, leading to protein loss due to reduced stability and moisture loss for nutrients like fat, ash, crude fiber, and carbohydrate (Rahaman *et al.*, 2016). These nutrients can be found in well-formulated snacks and composites. Research done in Uganda found that amaranth seed, which contains superior amino acids like lysine and essential amino acids, increases the level of protein content in composite flour. This resulted in an increase in protein content of 3.56 and 18.4 g/100g in the development of banana-based weaning flour made using soybean and amaranth flour (Oshaba *et al.*, 2021). Similarly, Aderoju *et al.*, (2020) observed that while the protein content of the composite flour of maize blends rose from 5.69 to 8.54% when made with yellow cassava flour and quality protein maize, the increasing proportion of maize flour had the opposite effect on calories. However, research from Kenya suggests that when making porridge for children, blending cassava-chia instead of just using cassava flour increases the porridge's protein content (Otondi *et al.*, 2020). Also, addition of more African yam beans to cassava increased the protein and amino acid components of the products developed (Omojokun *et al.*, 2021).

Another study conducted on jack bean seeds indicate that the protein content increased from 32.13 to 34.17% with increasing time of roasting due to the reduction in the level of antinutritional factors that are believed to be bound in the protein components of the legumes before processing (Odedeji *et al.*, 2019). Studies conducted on the processing of potatoes through solar drying and sun drying increased the protein content in snacks (Nicanuru *et al.*, 2015). Nevertheless, several studies have shown that eating composite flour consisting of soybean, maize and OFSP may result in the production of high-quality protein (Ndife *et al.*, 2020). In a different research, the protein content of blends of cassava and soy flour was found to be 31.5 g/100 g, higher than 3.35 g/100 g in pure cassava flour (Mosha *et al.*,

2010). This indicates clearly that formulation of nutritious foods through the development of snacks would increase nutrient content in foods (Nkhata et al., 2020). Therefore, the formulation of snacks using several flours would help to reduce the challenge of low nutrient intake among school children in primary schools in West Nile, as indicated in Table 2.

Study conducted by Fungo, (2020) on daily nutrients included in school lunches consumed by students by region or school is as indicated on table 1. The study indicates that schools in west Nile provided more Iron (5.1mg/100g) compared to the schools in the West (4.9mg/100g) part of Uganda whereas those in boarding schools had lower nutrient intake by about 21%. West Nile schools provide higher foods value rich in vitamin A (1535.2 µg per 100g) compared to only 546.5 (µg per 100g) in the Western Uganda schools, but the students from non-boarding schools had 1516.6 µg per 100g of vitamin A compared to 596.7 in boarding schools.

Table 1 shows list of nutrients consumed among children 6-15 years in primary schools. This list guided interventions that could be used to meet the nutritional gaps in foods currently being consumed particularly in primary schools to address the deficiencies.

2.5 Nutrient requirement for school-aged children

Table 2.0 indicates the recommended dietary allowances for children 6-15 years. Children 12 to 15 years need 37.5% more zinc compared to that for children less than 12 years, while children 12-15 years need 27.3% more iron compared to that required by children 6-12 years.

Table 1: Daily nutrients included in school lunches consumed by students by region or school

Region/School	No of children	Energy (kcal per 100g)	Protein (mg/100g)	Iron (mg/100g)	Vitamin A(µg per 100g)
West	50	880.0	24.9	4.9	546.5
West Nile	45	625.1	22.5	5.1	1535.2
North	35	602.3	16.7	3.3	367.2
East	50	637.1	19.5	4.3	386.5
Central	45	846.1	23.6	4.9	509.3
Private/public					
Private	140	702.9	19.8	4.3	418.9
Public	85	673.5	21.3	4.5	759.0
Primary	40	698.2	19.5	3.8	427.4
Boarding/nonboarding					
Boarding	105	711.9	28.2	5.7	596.7
Non -boarding	120	661.8	29.0	7.2	1516.6

Source Fungo (2023).

Table 1 indicates that primary school child only have an intake of 3.8mg of iron which is much less than the recommended RDA for iron for children

Table 2.0 indicates the recommended dietary allowances for children 6-15 years. Children 12 to 15 years need 37.5% more zinc compared to that for children less than 12 years, while children 12-15 years need 27.3% more iron compared to that required by children 6-12 years. It has been reported Globally, that children and adolescents are un able to meet their dietary intake intakes as recommended (Muñoz *et al.*, 2000).

Table 2.Recommended Dietary Intake for primary school-aged children

Age (years)	Fe (mg/100g) Male	Fe (mg/100g) Female	Zn (mg/100g) Male	Zn (mg/100g) Female	Vitamin A	
					Male	Female
6-8	10 mg per day	10 mg per day	5 mg per day	5 mg per day	400µgRAE	400µgRAE
9-13	8mg per day	8mg per day	8mg per day	8mg per day	600µgRAE	600µgRAE
14-18	11mg per day	15mg per day	11mg per day	9mg per day	900µgRAE	700µgRAE

Source: WHO 2008

Table 2 shows the recommended nutritional requirements for iron zinc and vitamin A for children 6-18 years. Children 6-8 and 9-13 years require 10mg and 8 mg of iron per day respectively, while girls 14-18 years would need 15mg per day. 6-8 and 9-13 year old boys and girls would need 10 mg and 5 mg per day, 8 mg per day is needed per day to meet the nutritional needs for iron and zinc respectively for both sexes. While children 14-18 years need 11mg of iron, 15mg of iron for boys and girls, 11 and 9 mg of zinc per day of zinc for boys and girls respectively. 400 µgRAE and 600 µgRAE of vitamin A is recommended for children 6-8 and 9-13 years respectively and those 14-18 years require 900 µgRAE and 700µgRAE for boys and girls respectively.

Dietary fiber in snacks

According to Reggi *et al.*, (2024) in a study conducted in Nigeria, crude fiber in foods served at schools contained between 0.8 to 1.3 mg per 100g. Snacks need to be prepared with low level of dietary fiber less than 5mg/100g due to high level of phytate binding with nutrients such as iron and could result in increased expulsion of essential nutrient from the body rather than being absorbed for healthy growth (Igbua *et al.*, 2020). However, studies show that crude fiber reduces diseases like cancer by reducing the gut's cholesterol content (Chuwa *et al.*, 2020). Snacks developed using more than 50% maize increased fiber content as more maize was added to the flour formulations (Abiodun *et al.*, 2020). Crude fiber requirement can be increased when wheat flour, soybean, carrot, mushroom and apple pomace powder can enhance the amount of crude fiber in noodles compared to the control noodle (Awofadeju *et al.*, 2021). Similarly, crude fiber in snacks can be increased by adding multiple flours such as 20% soy flour, 60% maize and 20% banana other study indicates that addition of OFSP and lima beans can result in crude fiber of 3.48–5.37 mg/100 g (Olaleye *et al.*, 2020).

According to Birungi *et al.*, (2023), cassava has 1.9 mg of crude fiber per 100g. The ability of the fermenting microorganisms to hydrolyze and oxidize enzymes to break down the crude fiber of the fermented blends has been shown to cause a loss in fiber content in previous investigations (Omojokun *et al.*, 2021). Similar to this, snacks containing 50% OFSP have a higher crude fiber content of 2.60–

4.20% (Ndife et al., 2020), However, despite the low level of crude fiber in the snack samples, the crude fiber content of maize and bean snacks decreased with substitution and variations in African oil bean seed flour formulation (Temba et al., 2017).

Energy requirement

Study conducted in Brazil indicates that the mean energy intakes was 2050.18 ± 966.83 kcal per day due to foods consumed by school children out school foods (De Lacerda *et al.*, 2023). Energy in the diets of school children is needed through the development of snacks that would provide sufficient calories per day with a minimum contribution of 25% of the recommended RDA for calories required per day (Naicker & Singh, 2020). Like in other studies, the highest energy content was 357.08 kcal/100 g, while the lowest value was 347.68 kcal. Foods with a high fat content have higher energy levels since it promotes children's growth and development (Makori et al., 2018). The emergence of food items derived from cassava also resulted in a rise in the amount of calories and a higher percentage of cassava flour (Odoh et al., 2022). However, no significant ($p > 0.05$) differences existed due to an increase in the proportion of cowpea and orange-fleshed sweet potato flour, which also significantly reduced ($p < 0.05$) the level of calories in the samples (Adigwe et al., 2023; Buzigi et al., 2020). Porridge made with 40% amaranth grain, 25% orange-fleshed sweet potato, 20% soybean, and 15% of the finest snack formulation was produced as a consequence of this retentive feature (Marcel, Chacha & Ofoedu, 2022).

Fat requirement

Nonetheless, additional research suggests that OFSP contains low fat that are essential for growth and development in children 6-15 years and could be improved flours are blended with other flours to form snacks (Alam & Islam, 2016). The levels of fat in the products vary with the products used the proportions of the flours blended (Kaur & Aggarwal, 2017). Accordingly, in Australia the recommended fat intake for children 5 years is 49 grams per day (Tesfaye *et al.*, 2024)

Ash content in snack products

Processing of flours through malting has been reported to reduce the level of ash in snack blends from 0.57 to 1.30% who noted that highest ash content was observed in the raw sample blends with values that ranged from 2.71 to 3.41%, while fermented blends had lower ash content that ranged from 0.57 to 1.30% (Omojokun *et al.*, 2021).

Similarly, Mahati *et al.*, (2018) in their study found that dehulling of grains reduces ash content in snacks but this reduction was insignificant when compared to undehulled grains. Roasting OFSP, however, increases the amount of ash (1.26–1.99%), crude protein (2.12–3.99%), crude fiber (0.45–1.55%), moisture decrease (72.44%– 50.23%), and carbohydrates (15.25–40.75%) in potatoes, all of which are markers of the presence of minerals in the product (Sulaiman *et al.*, 2019). Other studies indicate that roasting of jack beans instead reduced the level of ash from 4.67 to 4.39% (Odedeji *et al.*, 2019).

Essentially, the amount of ash in the composite flour indicates the amount of inorganic material. (Nafula *et al.*, 2021). Formulation of composite flours increases ash content as studied in Kenya when cassava-chia was blended compared to using cassava flour alone in making porridge for feeding children (Otondi *et al.*, 2020).

However, more research on the development of composite flours shows that the ash percentage ranges from 1.5% to 2.5%, with mixes including 61% maize, 35% pea, and 4% malted barley having the highest ash content. Conversely, the blends including 72% maize, 20% pea, and 8% malted barley had the lowest ash concentration, which increased as the percentage of pea increased (Fikiru *et al.*, 2016). The ash concentration of the various bean species varied significantly ($P < 0.05$). For instance, the African yam bean had the greatest mineral composition at 4.3%, followed by the soybean at 4.01% (Adamu *et al.*, 2015).

Moisture content in snack products

Based on research conducted in Malawi by Nkhata et al., (2020), The snack made entirely of wheat flour had a higher moisture content overall than the chin-chin snack made with blends of orange-fleshed sweet potatoes, soy beans, and maize, which had a range of 3.80 to 4.80%. This shows how the formulation of the flours affects the overall moisture content of the snack products (Ndife et al., 2020). One possible explanation for the decrease in moisture content might be the process of roasting, which causes the snacks to lose moisture (Sulaiman et al., 2019). Compared to cassava chia seed mixes, high quality cassava flour (HQCF) had a greater moisture content (10.09%) Otondi et al., (2020), higher than that of blends of cassava chia seed and creates a favorable environment for microbial growth, which ultimately lowers food quality through loss of valuable nutrients into the medium (Forsido et al., 2021).

According to research done in Ghana, the control cookies prepared with 100% cassava flour had a moisture content of $6.7 \pm 0.2\%$, but the cookies made with groundnut meal, ackee meal, and cassava had a higher moisture content of $7.5 \pm 0.2\%$ (Sahé et al., 2019). Another study conducted in Ghana indicate that control cookies made with groundnut meal, ackee meal and cassava had a higher moisture content ($7.5 \pm 0.2\%$) than the control cookies made with 100% cassava flour whose moisture level was $6.7 \pm 0.2\%$ (Adigwe et al., 2023). Generally speaking, potatoes have higher moisture content than other tubers like cassava due to the genetic composition of high level of carotene that has high moisture affinity (Bao, Badi and Fweja, 2020).

Iron content in snack products

Nodoushan *et al.*, (2021) reported that generally feeding of children could not meet all the nutritional requirement which were significantly lower than the RDA. Iron is important in oxygenating tissues and managing the processes of myelination and neurotransmission that occurs along with regulating the metabolism of neuronal energy via iron-containing enzymes (Kumari *et al.*, 2017). In order to boost the bioavailability of foods high in iron and zinc for school children conventional processing techniques

would increase bioavailability of iron (Nkundabombi *et al.*, 2015). A study carried out in Uganda show that the iron content of foods made with gari, silverfish, and soy flour was 4.4 mg per 100 g which was not sufficient to meet the nutritional requirement of iron for children 6-15 years (Eloolu & Ongeng, 2020). Comparably, 82% bean proportions were used in other Ugandan investigations to establish an iron concentration of 4.8 mg per 100 g in orange-fleshed sweet potato, amaranth seed, maize, and iron-rich bean (Roba1). Similarly, other studies carried out in Uganda using 82% bean proportions in the snacks made with orange-fleshed sweet potato, amaranth seed, maize, and iron-rich bean (Roba1) reported an iron content of 4.8 mg per 100 g (Natabirwa *et al.*, 2020). Tumuhimbise *et al.*, (2018), highlighted that the amount of iron in snacks derived from combinations of amaranth leaves and orange- skinned sweet potatoes might vary from 4.8 to 97.4 mg/100 g. Similarly, studies by found that the amount of iron in a snack mix consisting of amaranth seed, maize, sweet potatoes with orange flesh, and beans high in iron was 4.83 mg/100 g and 1.5 mg/100 g, respectively. Nevertheless, earlier studies show that malting NAROBAN2 increased the iron content of processed flour (Nafula *et al.*, 2022). These nutrients can be altered due to variations in the proportion of ingredients used in snacks; however, iron and zinc are retained in high amounts in processed beans

The zinc values of the samples ranged from 2.74 mg/100 g to 4.55 mg/100 g, but they were lower than those in the control snack (60%, 30%, 10%, maize, soy, and banana). It has been noted that several snacks are being sold to school going children, but their nutritional content is hardly known, and this needs to be overcome through the fortification of foods, as shown by previous study findings, which showed that the level of iron in the developed content of snacks was 4.8 mg per 100g using OFSP, maize, amaranth seed and the iron-rich bean (Raba 1) variety due to the high level of iron in the bean variety (Natabirwa *et al.*, 2020). These nutrients are obtainable from foods that are readily available in the area, however processing the food is necessary to boost their availability for children's healthy growth and development in elementary schools since these plant materials include anti-nutritional components (Terefe, Omwamba & Nduko, 2021).

Furthermore, research from South Africa indicates that cooking beans improves iron retention

Vitamin “A” content in snack products

Due to inadequate nutrient intake from poor diets, vitamin A nutritional deficiencies are a serious public health concern (Harika, et al., 2017; Sangalli et al., 2016). Foods sufficient in vitamin A must be included in school children's meals to prevent deficiency and preserve their health (Uzoaga et al., 2020). Certain foods are insufficient in vitamin A, so high-carotene foods like OFSP must be incorporated in snack development. This has been made possible in previous study that showed that formulated gari, soy and silver fish produced a nutritional content of 61.57 micrograms per 100 grams (Elolu & Ongeng, 2020). However, when the snacks have a high moisture content, which may be brought on by their low fat content, the availability of vitamin A is decreased (Gomes et al., 2017). Other studies indicate that formulated gari, soy, and silver fish resulted in a nutrient content of 61.57 µg/100 g vitamin A (Elolu & Ongeng, 2020). The vitamin A loss could be due to harsh processing methods and carotene degradation (Kaur & Aggarwal, 2017; Akande et al., 2017). However, as carotene is lypolytic and requires a high level of lipids to boost its bioavailability, this can diminish vitamin A efficacy. This might be mitigated by using bio-fortified maize and orange-fleshed sweet potatoes to raise the bioavailability of the carotene content.

According to Olapade and Ogunade (2014), Using bio-fortified corn and orange-fleshed sweet potatoes to increase the carotene content's bioavailability might lessen this. The e-level of βcarotene decreased as a consequence, from 140 to 187 µg/100 g. Additionally, it was noted that heat during processing caused carotene to degrade; light and oxygen may be the agents that accelerate the deterioration of total carotenoids (Oliveira et al., 2010). According to a different study, the dry matter basis ash content of sweet potatoes with orange flesh ranges from 3.3 ± 0.22 to $2.0 \pm 0.07\%$ (Nicanuru et al., 2015). The presence of other proximate contents of the snacks, such as protein, high moisture, and especially fats, results in increased β-carotene retention in snacks because they prevent the deterioration of vitamin A in snack goods by forming protein lipid complexes (Honi et al., 2017). Trans-β-carotene, which is

extremely susceptible to heat and light, causes the deterioration, which isomerizes to cis-isomers that are quickly lost from the snack mixes (Neela & Fanta, 2019).

These nutrients in OFSP are necessary and could be given on a daily basis, but because the crops are perishable, they must be processed into snacks in order to increase the amount of vitamin A the pupils in primary schools receive (Adebisi et al., 2020). The nutritional makeup of snacks can be enhanced by using OFSP with other cereal flours to create nutrient-dense snacks, although the majority of school children are currently fed starch or cereals lacking essential nutrients like vitamin A (Ndife, Nweke & Ezeocha, 2020; Bechoff, Taleon & Carvalho, 2017). The level of vitamin A reduces with the addition of other flours, such as soy flour, due to soy flour's ability to lower the amount of vitamin A in foods, basically due to the variation in the proportion of pumpkin and soy flour in the studies conducted in Tanzania (Adegunwa et al., 2020; Marcel et al., 2022). Based on research carried by Nikmaram et al. (2015), the level of vitamin A reduces with an increase in temperature when processing snacks. This suggests that utilizing OFSP to make snacks effectively might increase their ability to retain vitamin A by hardening the cell wall when combined with wheat. Additionally, OFSP has the potential to significantly increase the amount of ash and crude fiber in bread (Okporie et al., 2022). Some studies have shown that the level of vitamin varied between 180.5 and 232.2 µg RE/100g (Marcel et al., 2022). Similarly, other studies found that vitamin A was 1,437 µg RE/100g in a snack developed using pumpkin and bean flours (Marcel et al., 2022). Research indicates that the following nutrients are present in OFSP: zinc (1.42 mg/100 g), beta-carotene (20.01 mg/100g), protein (7.08%), iron (2.55 mg/100 g), (Dako et al., 2016; Gurmua et al., 2017).

Other studies show that there is variation in the level of carotene content among the OFSP varieties and that it can be retained through improved methods of drying and when the moisture content of the snack products is high (Momodu et al., 2022; Yemesrach et al., 2018; Mao et al., 2018). OFSP contains the minerals protein (7.08%) and carotene (20.01 mg/100 g) The level of vitamin A was high in snacks

formulated with an increased proportion of OFSP flour due to the high level of carotene in orange-fleshed sweet potatoes blended with Bambara and groundnuts (Honi et al., 2017).

2.5 The use of starchy staples, cereals and legumes in development of snacks for children

Bio-fortified sweet potatoes

Study conducted indicates that addition of more maize reduces pasting properties of snacks increasing water absorptions as well as increasing the nutritional quality aspects when 15% or green gram flour of 10% is used in product development (Singh et al., 2024). Similarly, bean have denser properties and when blended with rice flour can improve the colour and texture after baking additionally, combination of rice and beans in a ratio of 60:40 produced the most acceptable snacks with overall acceptability scores of 6.87 ± 0.73 . Mean values of 3.35 to 11.77% protein, 13.95 to 20.61%, ash 1.99 to 3.25%, fiber 1.66 to 4.67%, lipid 6.01 to 6.08% and carbohydrate 53.69 to 69.91%, respectively. Studies indicate that beans should not exceed 50% flour substitution to produce acceptable food products that is preferred by the consumers (Nwakunite *et al.*, 2024). Studies conducted by Olanrewaju, (2024) indicates that when snacks are developed by using sorghum, soybean, and almond seed in the ratio of 70:20:10, the micronutrients Na, Ca, K, Mg, Fe, Zn, and Mn were significantly ($p < 0.05$) higher this formulation while the macronutrients were crude protein (16.46mg/100g), Crude fat (4.31mg/100g), crude fiber (6.19mg/100g), Ash (3.29mg/100g) and moisture (12.03%) hence increase in the percentage of sorghum increased the level of ash indicating increased level of minerals (Olanrewaju, 2024).

Fermented cassava

Fermentation of cassava especially the bitter types is important in development of confectionery products such as snacks basically due to the high cyanide concentrations that can have a detrimental effect on human health especially school going children and therefore needs to be reduced (Nanyonjo *et al.*, 2021; Oloya *et al.*, 2017). HCN is poisonous and can cause death in humans, but effective

processing to remove it is not known by most farmers (Linda *et al.*, 2020). Fermentation of bitter and yellow cassava has been reported in other to reduce the acid content of the products (Olorode & Sobowale, 2021). This reduction in the level of HCN should be below 10 mg/kg as recommended according to the findings conducted in Nigeria through processing of cassava to form chips (Ishiwu *et al.*, 2015). This is contrary to sweet cassava varieties that have lower cyanide concentrations than ‘*Nyarudota*’ a local variety, which contains 88.50 mg/kg of hydrogen cyanide in the soils of Zombo district (Andama & Oloya, 2017) as compared to another variety that contains 53.23 mg/kg level of cyanide (Indasah & Muhith, 2020).

However, according to WHO (2005), 10mg /100g HCN in snacks is acceptable for human health (Indasah & Muhith, 2020). Whereas, Mehak (2018) noted that fermentation process detoxifies cassava pulp resulting in reduced level of HCN and good flavor developed. Sarkiyayi (2010) according to a study, bitter cassava varieties contain 440 mg/kg of HCN, whereas sweet cassava only contains 220 mg/kg. This means that sweet cassava can be used to make nutritious food snacks because the oxalates in it may chelate minerals like calcium, zinc, and iron, preventing the body from properly absorbing and using them and leading to malnutrition (Kuliahari *et al.*, 2021). Lactic acid bacteria have been seen to hydrolyze cassava starch into sugar, alcohols, and organic acids during anaerobic fermentation. This process is observed to grow during the course of fermentation, resulting in a decrease in pH and an increase in acidity (Abass, 2019). These nutrients differ amongst crops because of minute differences in their proximate composition, which may be caused by both genetic and environmental influences (Otondi *et al.*, 2020). Research has been done in Kenya on the creation of healthy biscuits by blending cassava flour with common bean milk instead of eggs. The outcome was the creation of biscuits with a fat content of more than 19.0% for cassava egg biscuits and 25.7% for cassava bean milk biscuits (Emilie *et al.*, 2022). To create snack items with excellent nutritional content and acceptability (desirability index of 0.97), 82% of the total components should be beans. Additionally, each 100 g of snack should have 20.4 g of protein and 4.8 mg of iron, with an average taste score of 5.7. (Natabirwa *et al.*, 2020).

However, fermentation of cassava improves the carbohydrate content and moisture with fermentation time by increasing the metabolisation energy values boosting the gross energy value and protein (Natabirwa *et al.*, 2020). The protein level is increased due to *saccharomyces cerevisiae* bacteria in fermented cassava (Pilajun & Wanapat, 2018). Additionally, it was found that the white gari had considerably more moisture (9.4360.1%) and ash (1.1960.01%) than the yellow gari (8.8860.03% and 0.8960.01%, respectively (Oluba, 2017).

Whole maize grain

Whole maize is a is an abundant source of essential nutrients, minerals, vitamin B, amino acids, and bioactive compounds like phenolics, carotenoids, phytosterols, beta-glans, and gammaoryzanol (Sanya *et al.*, 2020). However, white maize has less beta-carotene content than yellow maize (Samtiya, Aluko, and Dhewa, 2020; Onyeulo, 2022). Orange maize may be a substantial source of phenolic antioxidants and carotene, according to certain research (Beta & Taeyoung, 2018). It has been noted that processing yellow maize increases the retention of carotene content, making it suitable for snack product development (Nkhata *et al.*, 2020). These compounds make maize suitable for snack product development due to the low biological value of other flours (Oladapo, Adepeju, and Akinyele, 2017). In that, yellow maize contributes betacarotene when formulated with other flours to meet FAO's recommended daily intake of provitamin A. However, maize has limited amino acids, particularly lysine and tryptophan, making it poor in protein quality (Terefe *et al.*, 2021; Awoyale *et al.*, 2018; Nyakurwa *et al.*, 2017). As stated by Bello (2018), white maize, yellow maize, and corn maize flakes have varying protein, fiber, fat, ash, and moisture content. But fermented maize has lower moisture content due to a decreased porosity

Research has noted that the formulation of fortified maize meal with soy meal between 46.4% and 78.3% and 30 and 50% soy resulted in an increment in crude fat content (Rapando & Atsango, 2020). Likewise, when the amount of maize in the snacks grew, so did their moisture content. Similarly, the moisture content of the snacks increased with their quantity. Conversely, when 63% of the grain was

utilized, crude fiber was at its lowest and at its greatest percentage, 67.5%, of the grain (Fikiru et al., 2016); studies have been conducted that show that crude fiber was highest at 67.5% of the maize proportion and least when 63% of the maize flour was used (Fikiru et al., 2017). According to Beta and Taeyoung (2018) and Beta and Taeyoung (2018), since orange juice is a major source of antioxidants and carotene, the quantity of crude fat increased when enhanced maize meal was combined with soy meal at 46.4% and 78.3%, 30 and 50% soy.

Ash was reported to be higher in samples that had 20% yellow maize, containing a higher level of iron and zinc, indicating an increase in minerals in the snack samples with the addition of more yellow maize flour in snack formulations (Oyegoke, Adedayo & Fasuy, 2021). Germination of maize contributes to a high ash content in snacks due to the enzyme's activity in hydrolyzing the bond between the protein-enzyme mineral to free more minerals like phosphorous (Sharma et al., 2015; Bello & Udo, 2018). According to other research, using maize flour lowers the goods' ash level (Arisa et al., 2021).

Maize and rice flour when blended in the ratio of 80:20 produced a form gluten-free snacks with good organoleptic properties of taste colour and appearance, however when the rice proportion was increased by 20% it resulted into poor quality snacks quality of amaranth to expand (Gorach et al., 2024)

2.6 Anti-nutritional factors

Tannin

Tannin on the other hand, processing techniques like dehulling or boiling beans are required to remove the tannin and preserve the nutritional content of legumes in order to minimize tannin in the seed coat (Rahate et al., 2021; Mattila et al., 2018; Abbas & Ahmad, 2018). As stated by Nakitto et al. (2015), dehulling eliminates tannins from seed coatings and also makes protein more readily available for digestion, as well as improving the availability of iron and zinc.

Previous studies indicate a tannin level range of 0.09–0.22% reported by Omah & Okafor, (2015) for cookies made from blends of millet-pigeon pea composite flour and cassava cortex and 0.00 mg/100 g

to 0.03 mg/100 g for snacks developed using cocoyam Bambara Groundnut Flour Blends (Bulus et al., 2022). Furthermore, appropriate processing methods such as roasting decrease the level of tannin, phytates and soluble protein contents of bean flour in a snack sample (Aurelie et al., 2017). Snacks made with cocoyam-Bambara groundnut flour blends ranged in tannin content from 0.00 mg/100 g to 0.03 mg/100 g (Bulus, Nkama & Omah 2022). Other studies indicate that the level of tannin ranged from 2.34 to 8.15 mg/100g in composite flour developed in Nigeria using blends of maize, cassava and soy flour to form a composite flour that had the highest tannin content in the control composite flour containing 100% maize flour, which was significantly ($p < 0.05$) reduced, while the level was the lowest with a 20% soybean flour substitution, most likely due to the germination and dehulling of tannins contained on the seed coat of the soy beans (Igbua et al., 2020).

Patiballa *et al.*, (2024) documented that tannins can form insoluble red products for which an acceptable lethal dose of 90 mg/100g is recommended. This has been consistent with other studies that reported that the levels of phytate and oxalate were within the lethal range Previous studies indicate that the concentration of tannins in maize-based snacks is as low as 25 mg/100 (Nagel, 2010), However, research done in Tanzania with high-quality protein maize derived from cowpeas, common beans, and soybeans shows 0.12-3.5 mg/100g of tannin concentration (Maseta, & Mosha, 2016), Furthermore, tannin concentration in snacks also increases with an increase in bean flour (Awofadeju, 2021), which has similar effects on phytic acid oxalate (Lawal Oluranti & Enujiugha, 2016).

Studies indicate that mixing beans with maize, orange-fleshed sweet potato, and amaranth flours to form a composite, potentially reduces the overall tannin content (0.52 – 1.64 mg/100g) using formulation of soybeans and OFSP flours basically due to the dilution effect caused by the low tannin content of the flour formulation (Odiaka et al., 2024), most importantly different bean varieties contain different levels of tannin coupled with other flour ratios to that of beans as may be affected due to processing methods such as soaking, sprouting, roasting and milling resulting into production of snacks

of higher nutritional value (Ramos *et al.*, 2024). For instance, oxalate and phytate levels fell in formulations when the percentage of African yam bean levels was lowered (Awofadaye, 2021).

According to Mukuwapasi *et al.*, (2024), cooking and malting remove the high anti-nutritional factors that give raw amaranth seeds their bitter aftertaste. This arises from the fact that. A significant higher amount of oxalate, tannins, and phytate that are reduced, whereas mineral bioavailability relatively increases (Okafor *et al.*, 2018). Regarding oxalate, the range for snack mixes in cocoyam Bambara groundnut was 0.18 mg/100 g to 0.25 mg/100 (Bulus *et al.*, 2022).

Phytate

According to Patiballa *et al.*, (2024), anti-nutritional factors can be reduced by soaking before germination, as they can become toxic and cause kidney disease. Studies have shown that malting beans can also help reduce these factors in cereals like beans and maize can have reduced phytate levels hence improving the nutritive content and quality of snacks (Nafula, Ongeng & Alowo, 2022). This suggests that anti-nutrient levels can also lower the bioavailability of minerals such as iron, calcium, phosphorus, and zinc. Iron bioavailability is reduced by the interaction of minerals with anti-nutritional factors, forming insoluble phytate mineral complexes at physiological pH, however, some combination flours could have high amounts of phytate because maize lacks the enzyme oxalyl-CoA decarboxylase, which breaks down oxalate (Yang, *et al.*, 2018).

However, because maize lacks the enzyme oxalyl-CoA decarboxylase, which breaks down oxalate, some composite flours could have large amounts of phytate (Cowan *et al.*, 2024). Similarly, it has been seen that black gram fermentation reduces phytate as fermentation increases because phytate hydrolyzes to inositol and phosphoric acid, which releases the minerals that phytate has chelated and increases nutritional bioavailability (Ngungulu *et al.*, 2024). Similarly, Godrich *et al.* (2023), found that popping and roasting are two processing techniques that can lower the phytic acid level of red kidney beans and chickpeas unprocessed foods can limit children's access to mineral like Fe bioavailability due to insoluble phytate mineral complexes that occur at physiological pH (Karnika,

2016). Malted NARO Bean 2 may reduce anti-nutritional elements in legumes that have higher levels of anti-nutritional substances like phytates, between 8.10 and 16.36 mg/g of DM (Abbas & Ahmad, 2018).

Studies conducted in Nigeria indicate that the formulation of multiple flours such as maize, cassava and soybean resulted in the development of a food product with a phytate content that ranged from 1.02 to 1.43 mg/100 g with the highest content in the composite containing 70% cassava and 30% maize flour; however, the lowest value was observed in the sample with 20% soybean flour. The level was seen to decrease gradually in the product with the addition of more soybean flour (Igbua et al., 2020). The level of phytate polyphenols and oxalates reduced in fermented cassava composite flours (Digbeu et al., 2013).

Polyphenol

Plant compounds called polyphenols reduce the bioavailability of nutrients by forming complexes with iron and other cations through their carboxylic and hydroxylic groups. However, studies show that longer soaking and germination times significantly lower the amount of polyphenols in bean flour. This may be because longer soaking and germination times break down the covalent linkage within the solid endosperm matrix, but higher moisture content lowers the amount of polyphenol in snack foods. (Ndagire et al., 2015), The existence of polyphenol oxidase and other catabolic enzymes may possibly be the cause of this (Kumar et al., 2020). Along with this finding, other studies have shown that polyphenol is high in potato ranging from 40.20 to 64.30 mg GAE/100g in fresh tuber. This level can be reduced through processing of the potatoes since polyphenols have high solubility that increases their capacity to leach in the medium (Kaur & Aggarwal, 2017) much as polyphenols can reduce nutrient availability, they are required in foods since they play a critical role preserving foods by inhibiting the oxidation events that lead to food deterioration (Nilusha et al., 2021; Rahman et al., 2022). Other antinutrients can be reduced with increased flour formulation but the level of polyphenols increased in composite formulation having 200kcal, tannins in 300 and 550 kcal respectively (Alowo

et al., 2018). On the contrary, previous studies indicate that germination process did not lower the polyphenol content in NARO Bean 2 (Nafula et al., 2022). Research has shown that removing the 44 outer layers of grains may significantly reduce their phenolic content (Shahidi et al., 2021). Additional research carried out by Alowo et al., (2018), shows that in composite flours containing 200 and 300 kcal, respectively, malting did not significantly ($p > 0.05$) diminish the antinutritional components of tannin and polyphenol.

According to their research Zhaohong, et al., 2017, different species of legumes had varying levels of polyphenols. For example, french beans had the greatest polyphenol content at 11.44 mg/g D.W., bush beans had 4.68 mg/g D.W., and Romano beans had 3.21 mg/g D.W. These antinutritional factors can be reduced in legumes due to the process of germination followed by formulation with other flours (Ertop & Bektaş, 2018). Similarly, the total phenolic content of green chicken peas increased to 15.56 mg of GA equivalent per g dry weight after roasting and decreased to 7.80 mg GAE/g dry weight weight after germination (Kumar et al., 2020).

Hydrogen cyanide (HCN)

Previous studies indicate that traces of cyanide or cyanogenic glycoside, such as amygdalins and linamarin, are present in some non-cyanogenic crops such as beans and maize (Abe et al., 2015). Furthermore, research has revealed that the cyanide level of raw lima beans decreased from 76.70 mg/100g to 10.10 mg/kg, 10.40 mg/kg, 8.10 mg/kg, and 7.08 mg/kg in samples of roasted, germinated, cooked, and fermented lima beans, respectively (Olasupo et al., 2018). However, linamarin, a cyanogenic glycoside found in cassava that catalyzes the hydrolysis of glucose and acetone cyanohydrin to generate acetone and cyanide, is present in greater concentrations in bitter cassava (Oloya et al. (2018). Other studies found that high concentrations of cyanide can be 250.00 ± 2.53 mg/kg and (261.33 ± 3.51) mg/kg in maize and beans respectively (Adejoh et al 2020).

In Kenya, bitter cassava contains 2.16 mg/kg Hydrogen Cyanide concentration (Otondi et al., 2020). However, processing cassava tubers into flour through fermentation reduces this concentration and

therefore reducing public health risks, although bitter cassava varieties have over 10 mg/Kg HCN equivalent (Okoko, 2018). The formulation with 20% replacement of soybeans had the lowest amount of cyanide concentration, at 0.06 mg/100g, whereas the formulation having 100% maize flour had the lowest degree of acidity (Igbua et al., 2020).

In Nigeria, HCN of sliced cassava chips ranged from 7.10 to 9.15 mg/kg (Ishiwu et al., 2015). Similarly in the same country cyanide content was between 0.06 mg/100g and 0.36 mg/100g in composite flour formulated using maize, cassava and soy bean flour composite and highest 0.36 mg/100g found in composite formulation using 70% maize and 30% cassava. The lowest level of 0.06 mg/100g was in formulation containing 20% soybeans substitution had the lowest value and 100% maize flour had the lowest level of cyanide content (Igbua et al., 2020). Similarly, when composite flour was made, the amount of hydrogen cyanide was lower and the quantity of maize flour was higher (Aderoju et al., 2020). This finding was contrary to other studies elsewhere in which no cyanide was detected in maize (Eleazu et al., 2021). Furthermore, HCN reduced with addition of palm oil in yellow to $1.10 \pm 0.02 \text{ mg/100g}$ in yellow gari compared to $3.51 \pm 0.01 \text{ mg/100g}$ in white gari (Ismaila et al., 2018).

Table 3: The antinutritional factors in various food

Plant materials	Type of Antinutritional factors	Quantity per 100g
Legumes (soya, lentils, chickpeas, peanuts, beans)	Phytic acid Saponins Cyanide Tannins	386-714 mg/100g 106-170 mg/100g 2-200 mg/100g 1.8-18 mg/g 6.7 mg/100g 8 mg/kg
Grains	Trypsin inhibitor Oxalates	50-74
Grains (wheat, barley, rye, oat, millet, corn, spelled, kamut, sorgho)	Phytic acid	50-74 mg/g
	Oxalates	35-270 mg/100g
Pseudo-grains: quinoa, amaranth, wheat, buckwheat, teff	Phytic acid	0.5-7.3 g/100g
Nuts:	Lectins	0.04-2.14 ppm
	Saponins	
	Goitrogens	150-9400 mg/100g
	Phytic acid	
Nuts: almonds, hazelnut, cashew, pignola, pistachio, brazil nuts, walnuts, macadamia, etc.	Lectins	37-144 µg/g
	Lectins Oxalates	40-490 mg/100g
Seeds: sesame, flaxseed, poppy seed, sunflower, pumpkin	Phytic acid	1-10.7 g/100g
Tubers:	Alpha-amylase inhibitor	0.251 mg/mL
	Cyanide	140-370 ppm
	Oxalates Tannins Phytates	0.4-2.3 mg/100g
Tubers: carrot, sweet potato, Jerusalem artichoke, manioc (or tapioca), yam	Phytic	4.18-6.72 mg/100g
		0.06-0.08 mg/100g
	Phytic acid	0.82-4.48 mg/100g
Nigh shades: potato, tomato, eggplant, pepper	Tannins	0.19 mg/100g
	Saponins	0.16-0.25 mg/100g
	Cyanide	1.6-10.5 mg/100g

Source: Adapted from Popova & Mihayleva (2019)

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Study design

Study used both a cross-sectional and a complete randomized design (CRD). Sensory evaluation was conducted by the primary school pupils to select the best five snacks out of the nine snacks formulated using various flour proportions. The grains (maize and NAROBAN2) were germinated, dried, and roasted to form flours, then blended into snacks of various flour treatments in duplicates in comparison to the control sample. The laboratory design was chosen due to its capacity to control the treatment conditions and minimize errors (Rigo *et al.*, 2018). Quantitative data was collected for proximate, micronutrient, and ant-nutritional factors, with the exception of qualitative data collected on sensory parameters of color, taste, mouthfeel, and overall acceptability for snacks. Sensory evaluation was conducted in the school environment using a hedonic scale of 5 (liked most) and 1 (disliked most) acceptability (Alamu *et al.*, 2017).

3.2 Study area

The research was carried out in Ora County, Zombo District, West Nile, Uganda, about 65 kilometers by road west of Nebbi Town Council and about 70 kilometers from Arua City.

Zombo district is located at coordinates latitude: 2.5150; longitude: 30.9100) = 30° 54' 06E. The district neighborhood is bordered to the south by Nebbi District, to the west by the Republic of Congo, and to the north by Arua District. The study was conducted in Warr and Alangi sub-counties due to the availability of the NAROBAN2 variety being grown by a farmer group in Warr sub-county. In addition, the area is mainly inhabited by the Alur and Kebu tribal groups, whose traditional food is cassava and beans used in this study.

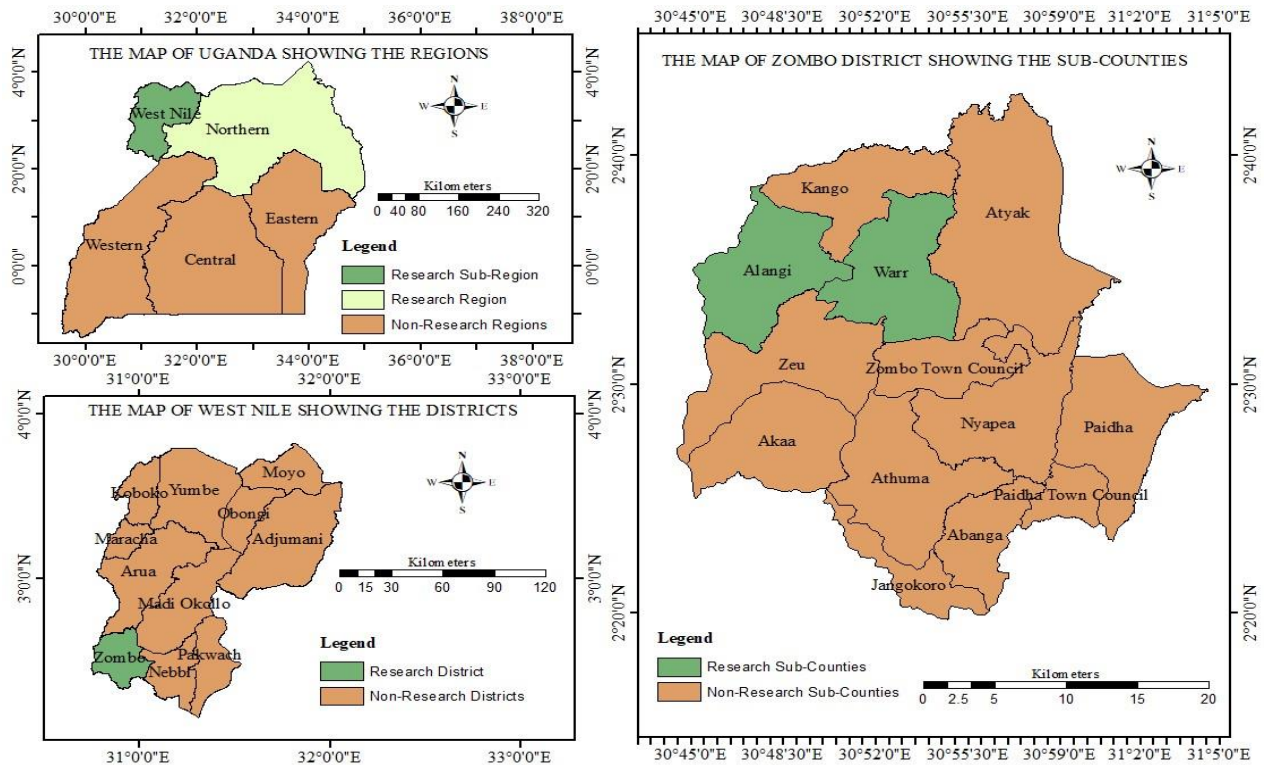


Figure 2: The map of Uganda showing West Nile Zombo district and research sub-Counties source (Ulango Tom, 2023)

3.3 Description of the population

A field study was conducted with the participation of pupils from Pasai and Mvuranyi primary schools in Alangi sub-county and Agiermach primary school in Warr sub-county. The study looked at developing snacks for these children since they are at their active growth stages that would need adequate nutrients while at school to compensate for the nutritional gaps exists compared to the one provided by the main meals. This would boost their academic performance through the intake of nutrients needed for cognitive development hence improved academic performance. However, children aged 8–15 years participated in sensory evaluation of the snacks due to their capacity to read and make decisions on the most preferred snacks meant to reduce undernutrition among the children. These children aged 6–15 years in rural primary schools have high deficiencies in iron, zinc, and vitamin A as they start primary school education when they are still undernourished when under 5 years old (Adejumo *et al.*, 2020).

3.4 Sample size estimation

The sample size for the sensory participants was calculated using the equation below Kolliesuah *et al.*, 2023).

$$n = \frac{z^2 pq}{e^2}$$

Where: n is the sample size; z is the confidence level at 95%, e = The precision level is set at 5% (0.05), p= the rate of undernourished students in the West Nile area is chosen to be 10.04% (0.104), q= the proportion of school children not undernourished Z, the confidence level at 95% (standard value 1.96), and q represents the fraction of the population that is not undernourished where: $q = (1-p) = 1-0.104 = 0.896$

Therefore,

$$\text{Sample size } n = (1.96)^2 \times 0.104 \times 0.896 / 0.05^2 = 143$$

When a non-response rate of 10% is added it gives an estimated sample size of 158 respondents.

3.5 Study Materials and Methods

About 75Kgs of 2 years old bitter cassava variety 'Nyarudota' was procured from a farmer in Cula village, Alangi Sub-County, Zombo District and processed to reduce the cyanide level (Oloya *et al.*, 2018). The variety was chosen because it produces quality local bread (kwen) due to the preferred flavour and the starch has high water holding capacity. Whereas, about 80kgs of OFSP was procured from a potato farmer in Arua district due to its high carotene level. The variety NASPOT12 was chosen due to its high level of carotene content that would provide vitamin A in snack development to reduce vitamin A deficiency (Haile1 & Getahun, 2020). In addition to this, NAROBean2 seed variety was purchased from one of the local Seed Business (LSB) groups in Zombo district.

The current study chose NARO bean2 variety was chosen as a primary source of iron, zinc dietary fiber because it is already being grown in the area of study for easy innovation adoption Affrifah *et al.*, (2023),. Furthermore, when malted, the level of phytate is reduced compared to NARO bean1 variety

as noted by Nafula, *et al.* (2021). White maize seeds were procured from Alangi main market in Alangi sub-county from different venders to provide a representation of the materials across the study area, Zombo district meanwhile yellow maize was procured from different stall at a temporary main market shade. Yellow maize was procured from Arua city since it was not available in Alangi at the time of collecting the raw materials. This was used as another source of carotene to complement that contributed by OFSP tubers as well as improve flavour of snacks (Sanya *et al.*, 2020; Beta & Taeyoung, 2018). On the other hand, amaranth seed was procured from a farmer in Cula village, Alangi Sub-county. The seeds were cleaned by removing extraneous matter and other plant parts before being stored for processing into flour.

3.5.1 Preparation of flours

3.5.2 Cassava flour preparation

Cassava was processed into flours using local processing method by harvesting using a hoe, peeled in the garden using a “sickle” shaped knife then transported home in a sack and partially sundried dried for about 2 hours on a clean papyrus mat. The tubers were then heaped in a corner of a grass thatched house, covered with dry banana leaves and left to ferment for a period of four days to detoxifies cassava pulp resulting into reduced HCN level and development of nice flavour (Sobarasua *et al.*, 2024). The tubers were then removed from the grass thatch house and place on a clean tarpaulin, mold was then removed using a blunt knife and the clean tubers pounded using a local motor locally known as “pany” (Alur language) and sun dried on a tarpaulin for eight hours to reduce moisture content and improve flour quality (Atlaw, 2020). After being dried, the cassava chips were ground into a fine flour at the Alangi Trading Center using a locally built grinding mill. The flour was mixed with other flours to form composite then sealed in plastic containers and kept at room temperature for future use to develop snacks.



Figure 1. Figure traditional fermentation of local cassava (Nyarudota) variety

Amaranth flour preparation

Amaranth hypochondriacus flour, one of the major sources of iron-rich foods, might be utilized in place of animal protein sources, particularly in places where school children rarely eat animal sources (Leticia *et al.*, 2023). Not only are they of high nutritional value and health-boosting but also improves texture of snacks therefore, increased intake of nutrients (Mukuwapasi *et al.*, 2024).

The grains were sorted and cleaned, sun-dried on clean tourpuline for 3 days, then popped or roasted using a source pan, resulting in a whitish color and a nice flavor. The popped seeds were then milled using a locally fabricated grinding mills at the Alangi trading center and stored in a plastic container at room temperature, ready to be used for composite formulation and snack development (Awolu *et al.*, 2024).

3.5.3 Orange sweet potato flour preparation

The Orange Fleshed Sweet Potatoes NASPOT12 variety was basically chosen because it contains higher level of carotene which is a precursor for vitamin to reduce vitamin A deficiencies

characterized by high morbidity, resulting into low attendance of children in schools. Orange colour of carotene in NASPOT 12 when used in snack development would result in development of snacks that are appealing to the consumers (Adoko 2021). The potatoes were prepared following a method described by Olosunde *et al.*, (2023). OFSP variety NASPOT12 in the current study were washed to clean excess soil then peeled using a sharp knife, washed thrice using clean water to remove any remaining extraneous matter. The peels, tops and other inedible pieces were disposed of (Haile & Getahun, 2020) and the tubers grated using a hand grater about 5 mm thickness and sun-dried for 3 days, milled using a fabricated grinding mill at Alangi trading center and flour stored in airtight plastic container for further use.

3.5.4 Preparation of maize flours

Yellow maize seed panner 38 was incorporated in the study due to its high level of carotene which is a precursor for vitamin A and would contribute to the vitamin A provided by NASPOT 12 potato variety. The seeds when popped have corny aroma that can improve on sensory appeal while white seeds Longe 5 variety was used due to high caloric level. The maize seeds were prepared using traditional method as described by Omojokun *et al.*, (2021). During the processing, white, and yellow maize seeds were sorted, cleaned, and soaked separately in clean water for 24 hours. The water was drained off and grains packed separately in locally made baskets whose interiors were covered with black cloth. Salt was then sprinkled on the grains to reduce the rate of mold development. The seeds were mixed once a day for a period of 4 days to enhance uniform germination and covered with part of the black cloth. After 4 days, the grains were removed from the separate baskets washed three times to remove and discard off the mold and radicles. The seeds were then sundried for 4 days, roasted, milled and packed in plastic containers ready for future use.

3.5.5 Preparation of NAROBan2 flour

NAROBan2 was used in the current study due to the high level of iron and zinc that would contribute to reduction of iron deficiency anemia. In addition, beans are also rich in folate that is used to form

DNA structure in body hence continuous growth of organs and subsequently cognitive development of the school children (Kok *et al.*, 2024). Bean seeds were processed using traditional methods as studied by Natabirwa *et al.*, (2018) by sorting, soaking for 24 hours and water drained off. The seeds were placed in a traditional basket and sprinkled with some table salt and mixed daily for a period of three days. The seeds were then cleaned and seed coat dehulled manually, washed with clean water and sundried for 4 days. The seeds were then roasted using a local source pan, milled using a locally fabricated grinding mill at Alangi trading center then stored at room temperature in an airtight plastic container ready to be used in formulation of composite.

3.6 Formulation of the composites and snack development

The flours, OFSP, cassava, maize (50% white: 50% yellow), amaranth seed and iron rich bean flours were weighed separately using a digital weigh scale according to their specific sample proportions then mixed in specific airtight plastic containers that was well labeled to ensure no cross contamination between and among the flours and composites respectively as indicated in Table 4. The 100g flours were then mixed to create composite flour, as shown in Table 4 which could be used to create snacks that would satisfy the dietary requirements for iron 10 to 12mg/100g, zinc 5 to 8mg/100g, and vitamin A 400 to 900µg/RAE that children in Zombo district primary schools should be receiving. In the meantime, Table 5 lists the ingredients that were added to each composite formulation prior to creating snack dough (Natabirwa *et al.*, 2018). Each of the 9 composite flours were mixed with the ingredients indicated in Table 5 then about 120 mls of clean water added to each of the composite flours while mixing the flours until the recommended dough texture was reached then placed separately in their respective containers for around forty-five minutes in the sun.

Once more, the dough was kneaded, meat mincer was used to develop cuboids of snacks which were cut about 1cm long and rolled between palms to form snack balls. The balls were baked using a locally made oven for about 25 minutes each while being turned at an interval of about 5 minutes in the separate baking trays until the snacks were well baked and cooled in open air.

Table 4: proportions of flours used in the development of snacks

Experiment	Sample snacks	<u>Flour formulations</u>				
		(OFSP: Cassava: Maize flour50%:(White: yellow) Amaranth : Iron Rich Beans)				
1	SP1	100	0	0	0	0
2	SP2	0	100	0	0	0
3	SP3	80	5	0	7	8
4	SP4	60	10	10	7	13
5	SP5	40	15	20	7	18
6	SP6	20	20	30	7	23
7	SP7	0	25	40	7	28
8	SP8	0	10	50	7	33
9	SP9	0	0	55	7	38

OFSP (Orange Fleshed Sweet Potatoes), CAS (Cassava), MZ (Maize), AM (Amaranth seed), IRB (Iron Rich Bean)

Formulations were made in duplicates for each of the snack category. The ingredients presented indicated in grams the quantity of each of the ingredients that was used in the development of the snacks to meet the micronutrient RDA for micronutrients (iron, zinc & vitamin A) of school children in primary schools. Where: OFSP (orange fleshed sweet potato, CAS (cassava), MZ (maize), AMA (Amaranth seeds) IRB (iron rich bean) flours and SP2 as control snack.

Table 5: Additives used per 100g snack formulation

Ingredients /Additives	Amount (g)	Amount (%)
Composite flour	100g	100%
Salt	2g	2%
Sugar	25g	25%
Powdered milk	10g	10%
Baking powder	1g	1%
Margarine	25g	25%

Ingredients presented in Table 5 were added to each of the composite indicated in Table 4 kneaded, baked and cooled in open air. The snacks were then stored in plastic containers ready for proximate and micronutrient lab analysis (Olapade, and Ogunade, 2014).

Photograph of composite flours

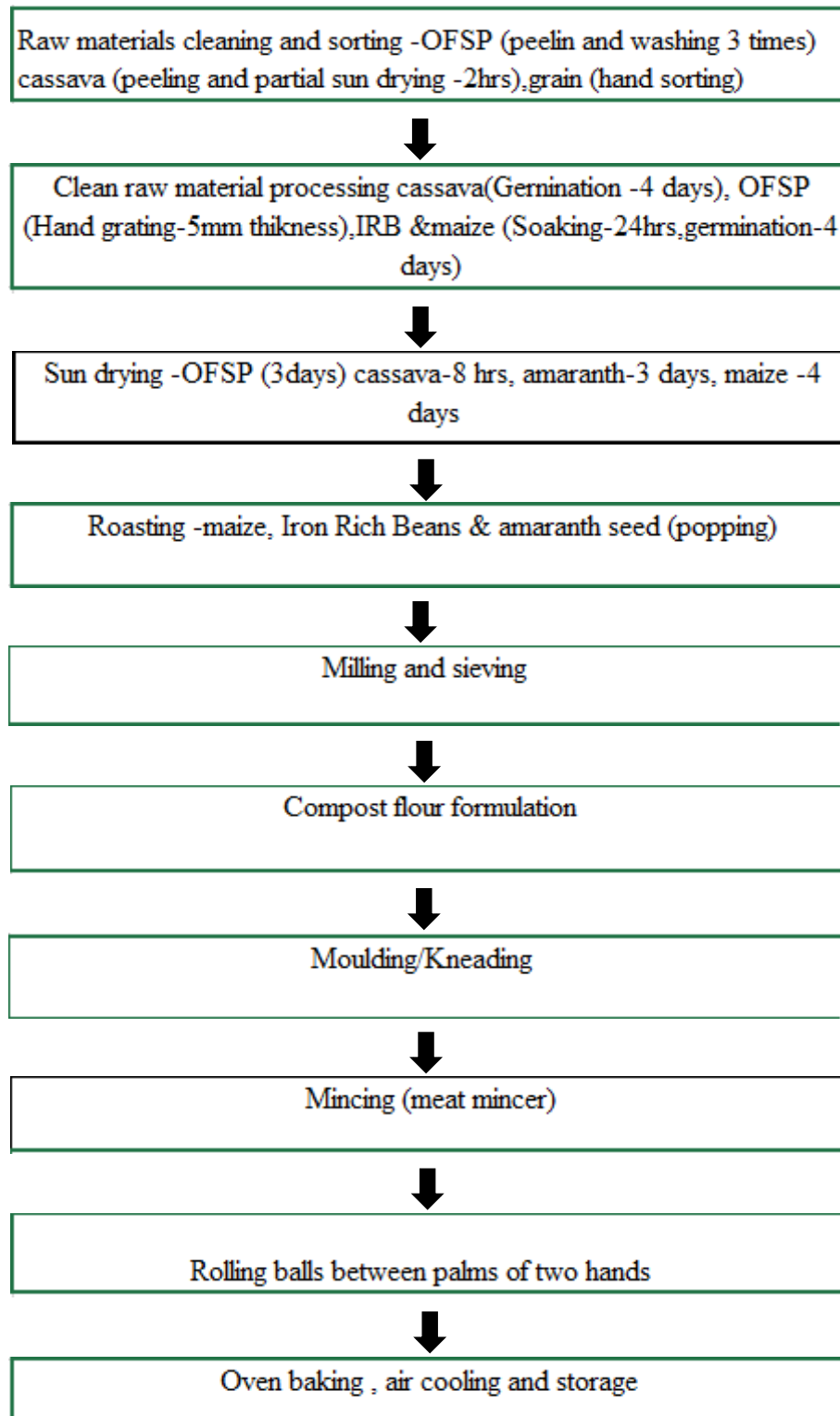


Figure: photographs of the composite flours



Figure: Photograph showing pupils from Agyermach primary school while evaluating the snacks for their sensory properties of taste, colour, and mouth feel flavour and preference

Figure 3. Flow chart for preparation of snacks using cassava, OFSP, maize, amaranth and iron rich bean flours



3.7 Determination of Consumer Preference and Acceptability of the prepared snacks

A study involving 130 pupils aged 8-15 from three primary schools carried out the sensory evaluation of nine snacks based on their reading and writing abilities and understanding of the questioner. The Hedonic scale of five was used to rate the snacks' color, flavor, mouthfeel, and overall acceptability. The results indicated that the snacks were slightly liked by the pupils (Jesulagba *et al.*, 2024).

3.8 Determination of proximate and micronutrient content of snacks

Proximate and micronutrient composition of 5 out of 9 best snacks SP2(control), SP3, SP5, SP6 and SP9 developed using cassava, maize, amaranth, iron rich bean and Orange Fleshed Sweet Potato flours to make a composite. These snacks were selected during sensory evaluation then later subjected laboratory test to determine the nutrient content which were compared with the nutrients in control snack SP2 prepared using 100% cassava flour.

3.8.3 Crude fat

The crude fat level was determined using Soxhlet extraction method of AOAC (2005). Petroleum ether was placed in a boiling flask and two grams of each sample was weighed and added to labeled thimbles, in an extract or the thimble was put , boiled, and heated. The Soxhlet apparatus was refluxed for 6 hours, and the thimble was removed. Most of the ether was distilled, and the flask was dried at 105–110 °C for 1 hour. The flask was then cooled, dried, and weighed and crude fat calculated using the equation below (Oluwaniyi & Oladipo, 2017).

$$Crude\ fat(\%) = weight\ of\ \frac{flask\ with\ fat\ (g) - weight\ of\ flask(g)}{weight\ sample(g)} \times 100$$

3.8.1 Crude Fiber

The crude fiber was determined using the AOAC (2005) reference method 978.10 as a standardized procedure conducted by Chauhan *et al.*, (2019). The process involved boiling five grams of the processed sample in a 150 ml of 1.25% H₂SO₄ solution for 30 minutes, washing it with hot water,

and then re-boiling it in 1.25% NaOH for another 30 minutes. The sample was then weighed, dried in an oven at 105°C and burned in a muffle furnace until only ash remained after 1 hr. After that, the sample was weighed, dried at 105°C in an oven, and then burnt in a muffle furnace until nothing but ash was left. Next, the weight of the fiber was measured and represented as a percentage of the weight of the sample. The characteristics of the fiber were examined using this technique (Ma *et al.*, 2023).

$$\text{Crude fiber\%} = \frac{(c - b)(d - b)}{a} \times 100 \dots\dots\dots\text{equation (1)}$$

Where, a = Weight of snack Sample b= Initial weight of crucible

c= Initial weight of crucible containing snack sample before ignition and d= Final weight of crucible containing ash after ignition.

3.8.2 Crude Protein

The crude protein content of a snack sample was determined using the Kjeldahl method and the KjeltexTM Model 2300 protein analyzer (Olawoye & Gbadamosi, 2017). The samples were digested at 420°C for 1 hour with organically bound nitrogen, and distilled ammonia was dissolved in a boric acid receiver solution and titrated using standard hydrochloric acid. Alkaline steam distillation was carried out, and Duma's concept and a blank experiment were used to determine the total nitrogen concentration.

$$\text{Percentage of Nitrogen(N)} = \left(\frac{(v1 - v2) \times N \times 14.007}{m} \right) \times 100$$

Where,

V1=volume of acid used in the titration for the blank (ml)

V2=Volume of acid used in the titration for the sample (ml)

N=Normality of the titrant acid (HCL) in ml

14.007=Molar mass of nitrogen (N) in g/mol

M= The mass of sample (g)

Therefore, $\%Crude\ Protein = 6.25 \times \%N (*Corection\ factor)$

3.8.4 Ash content

Ash was determined using Gravimetric method (Dry Ashing method) as reported by Nour, (2024). This study analyzed the ash content of foodstuffs after ignition or complete oxidation. 2 grams of samples were weighed into well-incinerated crucibles and ash in a muffle furnace at 550°C for 3 hours. The ash content was calculated using an equation.

$$Ash = \frac{W_A}{W_B} \times 100$$

Where,

WB is the weight of the sample and WA is the weight of ash.

3.8.5 Moisture content

The gravimetric method of AOAC Method 930.15 was used to determine the moisture content of a sample as conducted by Elloni *et al.*, (2024) . About five (5g) grams of the samples were weighed separately then placed in a moisture can which were dehydrated in an oven for 3 hours at 105°C, cooled, weighed, dried again in the oven. The weight of lost moisture was calculated and the percentage calculated using the equation below

$$Moisture\ content\ \% = \frac{w_3 - w_2}{w_1} \times 100$$

Where: w_1 is the weight of sample, w_3 initial weight of moisture can and sample before drying and w_2 is the final weight of moisture can and sample after drying.

3.8.6 Energy content

The energy content of snacks was determined using the bomb calorimeter method as described by Byaruhanga *et al.*, (2017). Dried snack was weighed, placed in a stainless-steel vessel filled with 30 atmospheric pressures of oxygen, and ignited at 1000°C. The heat created was recorded using a thermometer at intervals of 3 minutes until a stable maximum temperature was reached. The amount of energy needed to heat the water by 1°C was recorded and the physical calorific value displayed in units of joules (BTU per gram). This was the physical calorific value then the total caloric value was calculated using the formulae below.

$$(mg\ calories) = (\%CP \times 4.1) + \% Crude\ Fat \times 9.3 + \% CH$$

Where: FE is the food energy, CHO is carbohydrate and CF crude fiber

3.8.7 Zinc and Iron

An atomic absorption spectrophotometer was used to assess the zinc content of snack samples (Ngoma *et al.*, 2018; Awolu & Akintade, 2021). An average of two grams of each of the five samples were measured, ashed in a muffle furnace at 550°C until all the organic matter was burnt leaving ash product. The product was then dissolved in 20mls of HCl acid, filtered and the residue placed in a 100ml flask and tested in duplicates for the level of zinc. The final zinc content was calculated using a calibration curve for standard concentrations of 0, 0.5 ppm, 1.0 ppm, 1.5 ppm, and 2.0 ppm. The process involved a 100-ml flask, distilled water, and a calibration curve and zinc content expressed in mg/100g.

3.8.8 Vitamin A

The method of Light Emitting Diode as described by Neela, Satheesh, (2019) was used to determine the levels of vitamin A. About Five (5g) of crushed sample was weighed, 20 ml 50% NaOH solution added and warmed in a water bath at 90°C. Diethyl alcohol and hydroquinone solutions were added, and the water bath was maintained for 30 minutes. The contents were then poured into a decanting vial,

100 ml of water was added followed by 50 ml of ether then shaken thoroughly to ensure a uniform mixture. To this solution, 50 ml of petroleum ether were added and mixture and allowed to decant the extraction done twice with 50 ml of petroleum ether. The ether phase was washed three times with 100 ml of water, followed by filtering, evaporation, and concentration until 1 ml was obtained. Total carotenoid content was then determined using the Harvest Plus method and the spectrophotometer (Shimadzu AAS, Model AA-6300) to read the absorbance of the carotenoid at the wavelength of 450 nm. The value was then converted to vitamin A by dividing it by 12 conversion factors.

Vitamin A(μg)

$$= \text{Concentration of Betacaroten or Retinal } (\mu\text{g}/100\text{g}) \times \frac{\text{serving size}(g)}{100}$$

$$\text{Retinal Activity Equivalent(RAE)} = \text{Ratinol } (\mu\text{g}) + \frac{\text{Betacaroten}(\mu\text{g})}{6}$$

3.9 Antinutritional elements include phytates, hydrogen cyanide, polyphenols, phenols, tannins and oxalates.

3.9.1 Oxalates

The AOAC (2000) technique 974.24 was used to ascertain the oxalate concentration of two (2) g samples (Olaniyi *et al.*, 2024) . The samples underwent an hour-long digestion at 100°C after being suspended in distilled water and added to 6M HCl. measuring the filtrate, methyl red indicator was added. After heating the mixture to 90°C, it was cooled and filtered to get rid of any precipitates that included iron ions. Following a 5-minute centrifugation at 2,500 rpm with the filtrate combined with a 5% CaCl₂ solution, the mixture was dissolved in a 20% H₂SO₄ solution. There were 300 ml of filtrate in all. After heating filtrate aliquots to almost boiling point, they were titrated to a light pink hue using a standard 0.05M KMnO₄ solution. The formula was used to compute the calcium oxalate content, which was represented as calcium oxalate equivalent.

$$\text{Oxalate content} \left(\frac{\text{mg}}{100\text{g}} \right) = \frac{T \times V_{me}(Df) \times 105 \text{ mg}/100}{ME \times Mf}$$

Where: *T* is the titer value for KMnO₄ (ml), *V_{me}* is the volume mass equivalent (ie 1 cm³ of 0.05 M KMnO₄ solution is equivalent to 0.00225 g anhydrous oxalic acid, *DF* is the dilution factor (2.4), where the total volume of filtrate (300ml) is divided by the liquate used (125ml) for titration, *ME* is the molar equivalent of KMnO₄ in oxalate (KMnO₄ redox reaction) and *Mf* is the mass of the used flour.

3.9.2 Tannins

Tannin concentration was determined using the procedure of Gelatin method conducted by Maxson and Rooney (1972) (Mezgebo, Kiros, Tefera Belachew Lema, 2020). About 1% of methanol was added to one gram of sample was mixed with 1% Hydrochloric Acid in methanol, centrifuged at 1000 rpm for 5 minutes, and mixed with 5 ml of vanillin-HCl reagent. The absorbance was measured at 500 nm using a double-beam UV-Vis spectrophotometer. The tannin amount was calculated using the standard tannin curve, and the results were expressed in mg/g.

$$\text{Tannin} \left(\frac{\text{mg}}{100\text{g}} \right) = \frac{[(\text{Absorbance of Sample} - \text{Absorbance of black}) - \text{Intercept}] \times 4}{\text{Slope} \times \text{Density} \times \text{Weight of Sample}}$$

3.9.3 Phenolic content

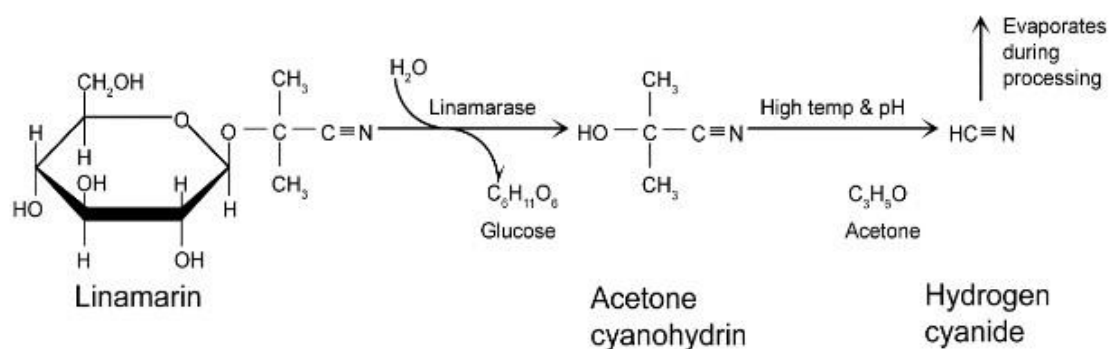
Phenolic compounds in snacks were determined using Folin-Ciocalteu method as conducted by Dominguez-lópez *et al.*, (2024). Snacks (SP2, SP3, SP6 and SP9) were extracted with methanol, centrifuged, and collected. The remaining pellets were extracted twice more, pooled, and concentrated. The samples were stored at -20°C until analysis. The total phenolic content was measured using the Folin-Ciocalteu method by Cox (2010). The solution was then dissolved in a 20% H₂SO₄ solution, resulting in a 300-ml filtrate. Aliquots were heated and titrated with a standard 0.05M KMnO₄ solution to a faint pink color. Calcium oxalate content was expressed as calcium oxalate equivalent and calculated using the formula

$$\text{Phytic acid in } \mu\text{g/g} = \frac{[(Ab-As)-\text{Intercept}] \times 10}{\text{Slope} \times w \times 3}$$

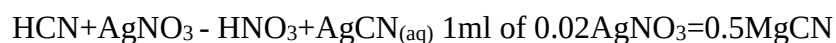
Where: *Ab* is the absorbance of the blank, *As* is the absorbance of the test sample and *w* is the weight of sample (grams).

3.9.4 Hydrogen Cyanide

The study used Essers (1995) and Konyo *et al.*'s (2019) methods (Enzymatic assay methods) to determine the cyanide content in fermented and formulated cassava-based snacks. Four (4) g of snacks were ground into flour and swirled in 25 ml of 0.1 M orthophosphoric acid then centrifuged at 6000 rpm for 15 minutes at 4°C. The supernatant of 0.1 ml was then added to 0.4 ml of orthophosphoric buffer (pH 7.0) followed by linamarase enzyme solution. The samples were incubated at 30°C for 15 minutes then 0.6 ml of NaOH added, 0.1 ml of chloramine T solution was mixed and shaken then color reagents added and mixed. The samples were incubated at room temperature for 10 minutes and the HCN measured spectrophotometrically after 20 minutes at a wave length of 605 nm. The cyanide contents calculated as total HCN using the formula below.



Hydrolysis of linamarin



$$\text{HCN} = \frac{(T - B) \times V_t \times 200}{A_t \times Q_t}$$

Where: HCN is the total cyanogenic potential in snack sample, V_t is the total volume of cyanide after dilution, T is the titer value for $AgNO_3$, B is the titer for blank, Q_t is the aliquot for sample used in titration and A_t is the total volume in the sample

3.9.5 Phytates

Wheeler and Ferrel (1971)'s method was used in the current study to determine the level of phytate in the snacks (Shama *et al.*, 2023). In this study, four (4) g of the grounded sample was soaked in 100 ml of 2% HCl for 3 hours and filtered through Wattman No. 1 filter paper. 2 milliliters of the filtrate were placed in a 100 ml conical flask. An indicator consisting of 53.5 ml of distilled water was added to the mixture when set to proper acidity and titrated with a standard iron (III) chloride solution till a brownish-yellow color appeared within 5 minutes.

The phytate content was then calculated using the equation stated herein

$$\text{Phytate (mole / Kg)} = \frac{T \times 564.11}{M}$$

Where: is value of the titration level of iron (III) chloride solution meanwhile M is the Molar mass of phytate

3.9.1 Data analysis

One-way analysis of variance was used to determine the snacks' acceptability in terms of sensory aspects that were preferred (ANOVA). These related to taste, color, texture and flavor as well as how they affected the acceptability of the snacks. In contrast, proximate, micronutrient and anti-nutritional factors were determined using one-way analysis of variance (ANOVA) with a 5% confidence level and a p-value of ($p < 0.05$) using sample t test (Konyo *et al.*, 2019).

3.9.2 Ethical considerations

Permission to conduct the study was granted by Gulu University Ethical Committee (GUREC) whereas, permission to conduct sensory evaluation of the snacks was granted by the the Chief Administrative

Officer (CAO) Zombo District (Appendix) these were in study areas of counties Warr and Alangi sub-counties. At the conclusion of the exercise, the participants received some little cash as a gesture of appreciation for voluntarily taking part in the study; they also recorded their comments based on their personal findings without any influence whatsoever.

3.9.3 Limitations of the study

A major limitation of this study is that all the maize and beans in the snack formulations were given the same treatments like soaking, roasting and malting, which made it hard to ascertain their effect on the proximate and nutritional composition of the snack formulations.

Evaluation of iron, zinc, and vitamin A bioavailability during soaking, roasting, and malting processes, as well as the microbial quality of the snacks was not conducted.

Effect of processing temperature on nutrients and antinutritional factors was not investigated in this study as nutrients could easily be lost thus, the question of whether these treatments added to the snack formulations did not have an additional impact on the nutrients' bioavailability and calls for further investigation.

CHAPTER FOUR: RESULTS

4.1 Sensory preference for cassava and OFSP-based snacks

4.1.1 Socio-demographic characteristics of study participants

Results in table 7 indicates that 68.5% of the total 130 participant were female. Considering specific schools of the 58 pupils from Mvuranyi primary school, 72.4% were female followed by 71% of the 45 participants from Pasai and 55.6% of the 27 participants from Agyermach primary schools. In relation to age, the majority of pupils were aged between 12 and 15 years, with the highest 96.6% of the 130 participants were from Mvuranyi and followed by Agyermach (96.3%) and Pasai (75.6%). As far as the education is concerned, the majority (96.3%) were in primary 5 and 7, while the highest proportion came from Agyermach (96.3%), followed by pasai (94.8%) and Mvuranyi (93.3%).

Table 6: Characteristics of the respondents

	Primary schools					
	<i>n</i> (45) <i>Pasai</i>		<i>n</i> (58) <i>Mvuranyi</i>		<i>n</i> (27) <i>Agyermach</i> %	
	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%
Total N (45+58+27)						
Sex of pupils Male						
	13	29	16	27.6	12	44.4
Female	32	71	42	72.4	15	55.6
Age						
8-11	11	24.4	2	3.4	1	3.7
12-15	34	75.6	56	96.6	26	96.3
Education level Below						
Lower primary (P5)	3	6.7	3	5.2	1	3.7
Upper primary 5-7	42	93.3	55	94.8	26	96.3

Table 7 presents sensory preference scores of cassava-based snacks. The results (Table 7) shows that increase and decrease in cassava and Orange Fleshed Sweet potato flour proportions resulted in a variation in the sensory properties of colour from lighter to darker colors in SP2 (100% cassava flour) and SP3 (80% OFSP:5% Cassava:0% maize:7%amaranth and 8% Iron Rich Beans) respectively. This resulted into snacks with more appealing colour to the pupils as such there was a variation in the colour score between the snack SP1 (2.47) (100% OFSP) to the highest colour score of 3.28. Furthermore, the results indicate that as more substitution of flours using higher proportions of maize, iron rich beans, there was significant ($p<0.05$) difference between snacks SP7 (0% Orange Fleshed Sweet Potato, 25% cassava, 40% maize,7% amaranth, 28% Iron Rich Beans flours), SP8 (0% OFSP, 30% cassava, 50% maize,7% amaranth, 33% IRB flours), and SP9 (0% OFSP, 0% cassava, 55% maize,7% amaranth, 38% Iron Rich Beans flours), and the control SP2 that had 100% cassava flour. The study noted a significant ($p<0.05$) preference for colour for snack SP8 compared to the colors of snacks SP7 SP9 and control (SP2). Addition of more iron rich bean and maize flours did not significantly ($p>0.05$) improve the final colour properties for SP1, SP3, SP4, SP5 and SP6 when compared to control snack SP2 that had 100% cassava flour. The study noted that addition of more flours was able to improve the highest colour score of snacks SP8 by 25% compared to that of the control snack SP2.

The study therefore, indicates that in order to develop snacks of good colour appeal using OFSP NASPOT12, cassava, maize (50%yellow and 50% white),amaranth and iron rich beans, the proportions of OFSP flour should be less than 60%, cassava less than 20%, maize 40 to 55% and Iron rich beans between 28 and 38% as indicated in table 7 similar to studies conducted using formulation of 15% OFSP,70% wheat, and 15% Banbara Groundnuts (BG) reported by Makhuvha *et al.*, 2024)

Substitution of cassava and OFSP flours using iron rich bean and maize flours did not significantly ($p>0.05$) improve taste of all the snacks ($p<0.05$) and the control SP2. However, the mean scores for taste indicate that snacks SP4 and SP5 had the most preferred taste. The study indicates that there was

generally an improvement in the taste of the snacks 2.95 (SP4) with increased flour substitution for cassava and OFSP flour but not significantly ($p>0.05$) by 27% score value of the control snack SP2.

Additionally, the scores for flavor for snacks SP3 were significantly higher than in snacks SP4, SP5, SP6, SP8 and the control (SP2) ($p<0.05$). Similarly, the scores for mouthfeel for snack SP6 were significantly ($p<0.05$) higher than snacks SP3 and control (SP2). Furthermore, SP3 was the most acceptable snack but had no significant ($p>0.05$) difference when compared control snack SP2 and among the snacks.

Table 7: Mean score of sensory characteristics segregated between formulations

Formulation	Colour	Taste	Flavour	Mouth feel	Acceptability
SP1	2.33±0.02 ^{cb}	2.81±0.31 ^a	2.63±0.05 ^b	2.66±0.40 ^a	2.79±0.22 ^a
SP2	2.47±0.53 ^a	2.08±0.36 ^b	2.17±0.43 ^a	2.13±0.25 ^c	2.28±0.50 ^b
SP3	2.45±0.34 ^{ab}	2.08±0.36 ^b	2.76±0.16 ^a	2.88±0.44 ^a	3.02±0.24 ^a
SP4	2.81±0.04 ^c	2.95±0.38 ^{ba}	2.71±0.14 ^a	2.16±0.02 ^d	2.77±0.53 ^a
SP5	3.01±0.06 ^{ba}	2.83±0.03 ^{ca}	2.67±0.07 ^a	2.72±0.36 ^{ab}	2.84±0.06 ^a
SP6	3.1±0.05 ^{ab}	2.67±0.18 ^a	2.69±0.07 ^a	2.96±0.07 ^a	2.81±0.03 ^a
SP7	3.2±0.01 ^a	2.53±0.14 ^{ab}	2.56±0.02 ^{ab}	2.67±0.03 ^{ba}	2.89±0.02 ^a
SP8	3.28±0.20 ^a	2.7±0.32 ^{bc}	2.67±0.06 ^a	2.61±0.06 ^{ca}	2.73±0.24 ^a
SP9	3.13±0.10 ^a	2.71±0.30 ^b	2.73±0.31 ^{ab}	2.67±0.00 ^{ac}	2.97±0.19 ^a

Values shows mean ±SD (n=5). For each category functional property snack parameter, means in the same column followed by similar superscripts are significantly different at 5% value of significance ($p<0.05$) and no significant difference with different superscripts ($p>0.05$).

SP1 (100:0:0:0:0), SP2 (0:100:0:0:0), SP3 (80:5:0:7:8), SP4 (60:10:10:7:13), SP5 (40:15:20:7:18), SP6 (20:20:30:7:23), SP7 (0:25:40:7:28), SP8 (0:10:50:7:33) SP9 (0:0:55:7:38)

Formulation flour (Orange Fleshed Sweet Potato, cassava, maize, amaranth and Iron Rich Bean Flours respectively).

Table 8: Overall preference of snacks

Paired Samples Test								
		Paired Differences				t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference			
					Lower Upper			
Pair 1	Sample snacks – preference	2.21111	2.55694	.49208	1.19962 3.22260	4.493	26	.000

The study indicates that use of composite flours to develop snacks significantly ($p < 0.05$) caused a difference among the snacks indicating that the sensory properties of snack blends developed using composite flours were more appealing to the school children.

Macronutrients in snacks

Macronutrients are presented on Table 11. The study indicates that crude protein was 26.48 mg per 100g ($p < 0.05$) higher in snack SP5 than 23mg per 100g in control snack (SP2). Similarly, there were no significant ($p > 0.05$) differences observed between crude protein components of snacks SP3 (18.37mg per 100g) and 20.55mg per 100g in snack SP9. Furthermore, the crude protein in snack SP3 (18.37mg per 100g) was lower than that of control snack SP2 20.6 mg per 100g, but with no significant ($p > 0.05$) difference between them.

Crude fiber content in snack SP3 was significantly ($p < 0.05$) higher than in snacks SP9, SP5 and control (SP2). Table 8 presents sensory preferences and acceptability of the cassava-based snacks. The results (Table 7) show that for the snacks SP7 (0% Orange Fleshed Sweet Potato, 25% cassava, 40% maize, 7% amaranth, 28% Iron Rich Beans flours), SP8 (0% OFSP, 30% cassava, 50% maize, 7% amaranth, 33% IRB flours), and SP9 (0% OFSP, 0% cassava, 55% maize, 7% amaranth, 38% Iron Rich Beans flours), there were significant ($p < 0.05$) differences in the scores for color between the snacks formulae. The study noted a significant ($p < 0.05$) preference for color for snack SP8 compared to the colors of snacks SP7 SP9 and control (SP2).

As far as the taste of the snacks is concerned, there were no significant ($p < 0.05$) difference in the score for taste between all the snacks and control SP2. However, the mean scores for taste indicate that snacks SP4 and SP5 had the most preferred taste. Additionally, the scores for flavor for snacks SP3 were significantly higher than snacks SP4, SP5, SP6, SP8 and the control (SP2) ($p < 0.05$). Similarly, the scores for mouthfeel for snack SP6 were significantly ($p < 0.05$) higher than snacks SP3 and control (SP2). Furthermore, SP3 was the most acceptable snack but had no significant ($p > 0.05$) difference when compared control snack SP2 and among the snacks.

Table 9: Preference of the three best snacks according to age and sex

Formulation	Male	Female	Male	Male	Female	Female
			8-11years	12-15 years	8-11 years	12-15 years
SP3	10	65	2	10	4	59
SP6	11	12	1	17	5	0
SP9	20	12	1	10	1	20
Total	41	89	4	37	10	79

Table 10 show preference of the best three snacks among school children 8-15 years by age and gender. The table 10 shows that the majority 79 participants were girls and only 41 were boys. Further analysis of the preference of the snacks, it was noted that 59 (75%) of the older children out of the total of 79 girls preferred snack SP3 as compared to only 25.3% who preferred snack SP9. However, none of the girls 12-15 years preferred snack SP6. For the case of boys 12-15 years, the majority (46%) of the 37 preferred snack SP6, however, 27% of the boys preferred snacks SP3 and SP9 equally. Boys 8-11 years (50%) mostly preferred snack SP3, while female of the same age range mostly (50%) preferred snack SP6 and the least (10%), preferred snack SP9.

4.2 Nutrient composition of cassava –OFSP based snacks

Previous study indicates that by incorporating cassava and OFSP flour would improve the nutritional content of cassava in providing nutrients such as vitamin A and iron which are generally low in cassava flour (Adoko *et al.*, 2021).

4.2.1 Proximate composition of cassava - OFSP -based snacks

Table 11 show the proximate composition of the preferred snacks. The results (Table 10) shows that crude protein was 26.48mg/100g ($p<0.05$) higher in snack SP5 than in snack SP6 (23.06 and control (SP2), there were no significant ($p>0.05$) differences observed between the crude protein components of snacks SP3 (18.37mg/100g) and SP9 (20.55mg/100g). The crude protein in snack SP3 (18.37mg/100g) was lower than that of control snack 20.6mg per 100g (SP2) but with no significant ($p>0.05$) difference between them. Furthermore, protein content was highest in snack SP5 ($P<0.05$) compared to the level in control snack SP2. Development of snacks using composite flours increased the level of overall protein content in snack SP5 from 11 to 22.2% in snacks SP3 and SP5 respectively. The study therefore noted that there was generally a significant ($p<0.05$) increase in the protein content in the snacks as a result of using composite flours compared to snack SP2 that had 100% cassava flour.

Table 10: Proximate composition of the most preferred cassava –OFSP based snacks
Sensory

Snack samples	Macronutrients					
	Crude protein (mg/100g)	Crude fiber (mg/100g)	Crude fats (mg/100g)	Ash (mg/100g)	Moisture (%)	Energy (kcal)
SP2	20.6±1.4 ^c	0.8±0.02 ^d	51.89±1.77 ^b	0.148±0.016 ^b	5.27±1.11 ^b	1611±21 ^a
SP3	18.37±0.25 ^a	6.43±0.18 ^a	56.71±1.15 ^b	0.135±0.002 ^b	12.37±1.26 ^a	1211 ±12 ^b
SP5	26.48±0.44 ^a	3.11±0.51 ^a	42.02±0.61 ^a	0.137±0.002 ^b	4.17±0.01 ^{ba}	812 ±18 ^a
SP6	23.06±0.16 ^{ab}	1.54±0.14 ^c	59.76±0.74 ^a	0.136±0.003 ^b	7.54±1.15 ^b	1137±21 ^{ab}
SP9	20.55±0.11 ^{bc}	5.25±0.14 ^a	57.40±1.77 ^a	0.135±0.003 ^b	5.37±3.32 ^{ab}	1332±24 ^a

Values (n = 5) display mean ±SD. Means in the same column with comparable superscripts are substantially different at the 5% level of significance ($p<0.05$) for each macronutrient and snack parameter; no significant difference is shown with different superscripts ($p>0.05$).

Table 10 indicates the level of crude fibers in snacks. The current study indicates that crude fiber content increased in snack (SP3) to 6.43mg per 100g which was significantly higher than 1.54 mg per 100g (SP6), 5.25mg per 100g (P9), 3.11mg per 100g (SP5) compared to 0.8mg per 100g in control

snack (SP2). The current study indicates that addition of more flours such as maize and beans in the formation of composite and subsequently developing snacks significantly increased levels of crude fiber content in snack 1.54 mg per 100g (SP6) by 48% as compared to the level 0.8mg per 100g in control snack SP2. The crude fiber in SP3 increased by 87.7% compared to control snack SP2 that had only 0.8 mg per 100g indicating that development of snacks using composite flours composite increased the crude fiber content of snacks.

As noted in table 10, levels of crude fiber 6.43 ($p<0.05$) significantly increased in all the snacks with addition of more flours compared to the level (0.8mg per 100g) in control snack SP2 which is possible while reducing the proportion of cassava flour (Table 10). Similarly for Ash, in table 10, there a significant ($p>0.05$) an increases in Ash from 0.135mg per 100g ($p>0.05$) in snack SP3 as compared to 0.148mg per 100g in control snack (SP2). Similarly, the study indicates that Ash generally decreased in all the snacks compared to the level of 0.135 mg per 100g in control snack SP2. Therefore, there the study noted that there was an overall significant ($p>0.05$) decrease in the level of Ash with addition of more flours to substitute cassava and Orange Fleshed Sweet Potato Flour that resulted in the development of snacks with a significant difference in their mineral levels.

Table 10 clearly indicates that proximate and micronutrient content in snacks varies with variation in the proportions of the flours used in this study. The study indicates that there was generally a significant difference ($p<0.05$) in the levels of both proximate and micronutrient content of snacks with increased addition of cassava and OFSP flours.

Table 11: p-value for macro and micro nutrients test results

Proximate and micronutrients	One-Sample Test					
	Test Value = 0					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Protein	15.771	4	.000	21.81200	17.9720	25.6520
Crude Fiber	3.201	4	.033	3.42600	.4548	6.3972
Fats	16.975	4	.000	53.55600	44.7966	62.3154
Ash	56.691	4	.000	.13840	.1316	.1452
Moisture	4.748	4	.009	6.94400	2.8838	11.0042
Iron	7.899	4	.001	37.56600	24.3620	50.7700
Zinc	8.504	4	.001	5.34800	3.6019	7.0941
Vitamin A	9.270	4	.001	1086.13200	760.8335	1411.4305
Calories	17.543	14	0.000	1220	1071.3744	1369.8256

SP1 (100:0:0:0:0), SP2 (0:100:0:0:0), SP3 (80:5:0:7:8), SP4 (60:10:10:7:13), SP5 (40:15:20:7:18), SP6 (20:20:30:7:23), SP7 (0:25:40:7:28), SP8 (0:10:50:7:33) SP9 (0:0:55:7:38)

Formulation flour (Orange Fleshed Sweet Potato, cassava, maize, amaranth and Iron Rich Bean Flours respectively).

4.2.2 Micronutrient content of cassava - OFSP based snacks

Iron content in snacks

Table 12 shows the micronutrients (iron, zinc and vitamin A) in cassava-OFSP based snacks. Snack SP6 (Table 12) had a significantly 44.01mg per 100g ($p<0.05$) higher content of iron compared to snacks with 40.9 mg per 100g (SP3), 43.95 mg per 100g (SP5), 40.17 mg per 100g (SP9) and control snack (SP2) 18.8mg per 100g ($p<0.05$). The lowest amount of iron was 18.8mg per 100g (SP2) formulated using 100% cassava flour. Generally, the study documents that that there was a significant ($p<0.05$) increase in the level of iron in all snacks 40.9 mg per 199g, 43.95 mg per ,44.01mg per 100g

and 40.17mg/100g in snacks SP3, SP5, SP6 and SP9 respectively. Formulation of snacks using several flours increased the level of iron in the current study.

Zinc content in snacks

The study indicates that only snack with 7.17 per 100g of zinc in snack (SP9) had a significant ($p<0.05$) increase in zinc content higher than 4.71mg per 100g, 5.70mg per 100g, 5.78mg per 100g in snacks SP3, SP5, SP6 respectively compared to 3.38 mg per 100g in control (SP2). Snacks SP3, SP5 and SP6 had insignificant ($p>0.05$) increase in zinc content with the lowest being 3.38mg per 100g in control snack SP2 containing only cassava flour while snack SP3 had 4.71 mg per 100g zinc among the snacks made using more than one flour type. It is noted that the level of zinc increased between 28.3% and 53% in snacks SP3 and SP7 respectively.

Vitamin A content

The results on the level of vitamin A is indicated in table 12. The study indicates that snack SP3 had significantly ($p<0.05$) higher vitamin A content of 1441.33µg per 100g compared to 1252 µg per 100g,(SP5), 1051 µg per 100g (SP6), 874.66 µg per 100g (SP9) and the control snack SP2 µg per 100g. The lowest level of vitamin A was in control snack SP2 containing 1005 cassava flour. Table 11 indicates that there was a significant decrease from 1,441.33 µg per 100g of vitamin A (SP3) with reduced proportion of OFSP flour. The level of vitamin A reduced among the snacks developed using composite flour between 7.1 and 44% in snacks SP9 and SP3 respectively. Therefore, the level of vitamin A reduces with reduction in the level of OFSP flour (Table12).

The study results (Table 11) indicates that snacks developed from cassava –OFSP composite flours had a significant change in the levels of iron, zinc, and vitamin A, however, SP9 had the highest significant ($p<0.05$) difference in the level of zinc with increased substitution of cassava and OFSP flours whereas, there was a significant reduction in the level of vitamin A with reduction in proportion of OFSP flour by 7.1% using 0% OFSP flour but increased by 44% in snack SP3 using 80% OFSP flour proportion.

Table 12: Mean micronutrients content of cassava-OFSP based snacks segregated by formulations

Sample formulations	Fe(mg/100g)	Zn(mg/100g)	Vitamin A (µg/100g)
SP2	18.8±0.83 ^c	3.38±1.40 ^a	812±8.00 ^c
SP3	40.90±0.9 ^b	4.71±0.05 ^{ab}	1441.33±6.67 ^a
SP5	43.95±2.05 ^{ab}	5.70±0.01 ^{ba}	1252±8.00 ^{ab}
SP6	44.01±1.39 ^a	5.78±0.07 ^{bc}	1051.0±5.0 ^b
SP9	40.17±1.67 ^{ab}	7.17±0.23 ^a	874.66±17.34 ^c

Values (n = 5) display mean ±SD. Means in the same column with same superscripts are substantially different at the 5% level of significance (p<0.05) for each functional property category and snack parameter; there is no significant difference when the superscripts are different (p>0.05).

4.3 Anti-nutritional factors in Cassava – OFSP based snack formulations

Table 13 indicates the antinutritional factors in cassava-OFSP based snacks. The concentrations of important antinutritional ingredients in the cassava –OFSP based snack formulations are shown in the table 13. In general, snack SP9 had 2.62 mg per 100g of oxalate and 4.53 mg per 100g hydrogen cyanide which were significantly higher than 1.75mg per 100g and 0.87 mg per 100g in snack SP3 respectively, 1.19 mg per 100g, 0.97 mg per 100g in snack SP5, 1.70 mg per 100g, 1.14mg per 100g in snack SP6, and 1.15 mg per 100g, 1.67mg per 100g in control snack (SP2). On the other hand, compared to snacks SP3, SP5, SP6, and SP9, the control (SP2) had 2.74 mg per 100g and 1.76 mg per 100g of tannin and polyphenols respectively and significantly (p<0.05) greater than the levels 1.79mg per 100g and 0.15 mg per 100g, 1.33 mg per 100g and 0.47mg per 100g, 2.26mg per 100g and 0.21 per 100g respectively. In addition, 2.79 mg per 100g of tannin in snack SP9 which was made with many flours has a far greater tannin content than 1.79 mg per 100g (SP3), 1.33 mg per 100g (SP5), and 0.98 mg per 100g (SP6). The findings also indicate that 48.78 mg per 100g of phytate in snack SP3 had a considerably (p<0.05) greater than 1.02 mg per 100g, 1.68 mg per 100g, and 2.24mg per 100g in snacks SP5, SP6, SP9 respectively compared to 1.52 mg per 100g in control (SP2).

Table 13: Mean content of Antinutritional factors in the formulated snacks

Anti-nutritional factors	SP3	SP5	SP6	SP9	SP2 (CONTROL)
Oxalates (mg/100g DW)	1.75±0.12 ^{ba}	1.19±0.26 ^{ab}	1.70±0.02 ^b	2.62±0.13 ^a	1.15±0.01 ^a
Tannins (mg/100g DW)	1.79±0.03 ^a	1.33±0.01 ^{ab}	0.98±0.01 ^a	2.26±0.03 ^a	2.74±0.03 ^a
Polyphenol (mg/100g DW)	0.15±0.00 ^a	0.47±0.01 ^a	0.37±0.02 ^a	0.21±0.01 ^a	1.76±0.08 ^a
Hydrogen Cyanide (mg/100gDW)	0.87±0.14 ^c	0.97±0.06 ^c	1.14±0.07 ^b	4.53±0.03 ^a	1.67±0.09 ^a
Phytate (mg/100g)	48.78±5.55 ^a	1.02±0.18 ^d	1.68±0.04 ^b	2.24±0.28 ^b	1.52±0.28 ^c

Values shows mean ±SD (n=5). For each functional property category and each snack parameter, means in the same row followed by similar superscripts areh significantly different at 5% level of significance ($p<0.05$) and no significant difference with different superscripts ($p>0.05$).

Table 13 shows test results on antinutritional factors in snack samples. The results indicates that formulation of the snacks using composite flour had an overall significant difference ($p<0.05$) in the level of tannin and phytate but not in the levels of polyphenol, hydrogen cyanide and phytate. Overall results and the hypothesis testing indicate that addition of more flours significantly ($p<0.05$) increased phytate, tannin and polyphenols by 65, 21.2 and 91% in snacks SP9, SP, and SP3 respectively. The levels of hydrogen cyanide and phytate reduced in snacks with addition of more flours between 63.1 and 32.1% in snacks SP9 and SP3 respectively.

Table 14: Test results on Antinutritional factors

	Test Value = 0					
	T	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Oxylates	6.335	4	.003	1.68200	.9448	2.4192
Tannin	5.503	4	.005	1.80200	.8929	2.7111
Polyphenole	1.990	4	.117	.59200	-.2339	1.4179
Hydrogen Cyanide	2.671	4	.056	1.83600	-.0728	3.7448
Phytate	1.171	4	.307	11.04800	-15.1478	37.2438

Table 14 indicates that the levels of polyphenol, hydrogen cyanide and phytate did not significantly ($p>0.05$) change with addition of more flour types as compared to oxalate and tannins that significantly ($p<0.0$) change with use of more flour types in formulation of the snacks.

CHAPTER FIVE

DISCUSSIONS

5.1 Sensory preference for cassava and OFSP-based snacks among primary school children

Colour preference

Snacks are essential for feeding children in primary schools as they provide a significant amount of energy, assist in ensuring children get the nutrients they require between meals and help them reduce hunger (Shah *et al.*, 2017; Natabirwa *et al.*, 2020). However, during the processing of these snacks, sensory attributes such as taste, mouthfeel, color and flavor are often altered and these consequently determine the overall acceptability of the products (Eloolu & Ongeng, 2020). As a result, sensory evaluation employing the different sensory attributes becomes a crucial element that supports acceptance of food products after processing (Sanya *et al.*, 2020; Sahé *et al.*, 2019). This is important in snack development while utilizing local food supplies and technologies. The current study investigated consumer acceptance and preference for snacks made from cassava and OFSP. Pupils were given eight (8) different formulas, each of which contained a different ratio of orange-fleshed sweet potato, cassava, maize, amaranth seeds, iron-rich bean and the control (100% cassava), in order to determine which formulas they preferred (Table 7). According to the results of the current study (Table 7), snack SP8 (3.28) had significantly ($p < 0.05$) higher score for color than those for snacks SP7 (3.2), SP9 (3.13), and control SP (2.47) ($p < 0.05$). The high proportion of yellow maize flour and iron-rich bean flour in the snacks (Table 4) may explain why snack SP8 had higher mean scores for color than other snacks. The colour for snack SP8 could have improved due to milliard reaction that took place when roasting beans and maize hence darker and more preferred snack colour (Schutte *et al.*, 2024).

Cereals and legumes typically have a lighter shade of brown that is more appealing, along with a redder complexion (Ndagire *et al.*, 2015a). This is in line with previous research by Kubuni *et al.* (2022) and Natabirwa *et al.* (2018), who found that increasing the amount of yellow maize flour and bean flour boosted snack preferences and acceptance.

Similarly, earlier research on the development of snacks in South Africa found that using different combinations of maize and baobab led to variations in the color of the snacks (Netshishivhe *et al.*, 2019). Additionally, Dewidar & El (2020), found that adding more by products of Brocken White Bean Flour (BWBF) when combining it with maize flour improved the color of snacks. This finding was consistent to both current previous study of Oduro-Obeng & Plahar, (2017), which noted that flour samples prepared using Brocken rice fractions, soy beans and OFSP flours were used for developing final composite in which case 60% wheat flour, 10% rice flour, 15% OFSP and 15% soy bean used for making cakes and biscuits that were preferred for their colour and taste.

In contrast, other studies noted that color did not significantly affect the preference and acceptability of snacks (Folorunso & Ojo, 2021; Badiu & Babawande, 2020). However, in this study, color most importantly in darker snacks was most likely due to the darker color of both maize and bean flour that reduced the color score in snack SP9 and SP7 (Fikiru *et al.*, 2016).

Furthermore, findings of the current study indicates that to develop snacks of preferred color, the proportions should be greater than 30% for maize, 23% for iron rich bean but less than 20% for cassava and OFSP flours. Therefore, promotional initiatives must be stepped up to emphasize the value of consuming food with vibrant color in order to counteract the generally lower preference for color contrary to that preferred in previous studies (Oduro-Obeng & Plahar, 2017). This implies that the color of snack formulations varies with variations in the proportions of the ingredients used (Elolu & Ongeng, 2020). The current study had improved colour preference with reduction in the proportion of OFSP flour from 80% in SP3 to 30% in snack SP8 most likely due to bright orange color of OFSP is due to the dark colour of beta-carotene that was outstanding in the snack (Makhuvha *et al.*, 2024) Therefore, having various proportions of flours in the snacks have an effect on the color preference of the pupils in primary school as these would ultimately determine the final product color (Bork *et al.*, 2024).

Taste and flavor preferences

The results further demonstrate that snack SP4 had the highest ratings for taste compared to the other snacks (Table 7). This can be attributable to malting which increases the level of sugar and lowers levels of antinutrients that increases bitterness, off-flavors, and unpleasant after taste resulting from the mixing ratios used in the snack SP4. For instance, snack SP4 was made up of 60% orange-fleshed sweet potato, 10% cassava, 10% maize, 7% amaranth seeds, and 8% iron-rich bean. This implies that antinutrients level contribute to the bitter taste was lower in cassava flour since only 10% was used in the snack (Adubofuor, Anomah & Amoah *et al.*, 2018). On the other hand, in accordance with Gawande & Babar, (2018), malting enhances the appearance, taste and flavor of beans by producing hydrolytic enzymes that are present in malted grains and legumes. These processes may have given the sample a better taste by converting the complex macronutrients such as starches, fats and proteins into more simpler sugars and therefore contributing to the most preferred taste of snack SP4 this is consistent with a study by Bello & Udo (2018) which demonstrated that malting increased the average mean taste score of bread made from soybean flour from 3.35 to 5.35.

Additionally, results in table 7 indicates that flavour score for snack SP3 were significantly 2.76 ($p<0.05$) higher than for snacks (2.71) SP4, (2.67) SP5, (2.69) SP6, (2.67) SP8, and the control (2.17) (SP2). This could be attributed to the low levels of antinutrients in cassava flour, malting, and roasting, as well as the composite ratios. This finding is as a result of the proportion between 5-25%, 10-80%, 50-55% of cassava, OFSP and maize produced snacks of preferred flavour. This finding is in agreement with earlier studies that produced snacks using 70% wheat, 15% OFSP and 15% Bambara Groundnut (BG) noted by (Makhuvha *et al.*, 2024). The improvement in flavour and aroma of the finished product particularly during roasting could have occurred due to release of volatile chemicals such as acetic acid and carbodioxide from the composite of cassava and OFSP (Omojokun *et al.*, 2021) (Nkundabombi *et al.*, 2015). This finding is in line with a study by Ndagire *et al.* (2015) in which malting and roasting enhanced the flavor and consequently, preference of bean-based composites as compared to unmated

maize porridge. In contrast to this, a study by Adoko *et al.* (2023) showed that roasting and malting decreased the flavour in iron rich beans and grains, making them less acceptable for children 2-5 years. Therefore, use of many flours to develop snack had a significant ($0 < 0.05$) improvement in the preference of the snacks for flavour by 21.4% in snack SP3 compared to the score level of 2.17 in control snack SP2 and in line with study by Nande, (2024). The study confirms that preference of the snacks for flavour will be affected by the variation in the proportions of different flours in snack formulations changes, that will influence snack flavour leading to variation in consumer preferences as claimed by Mmbone *et al.*, (2023).

Mouth feel

As far as the scores for mouthfeel is concerned, snack SP6 had significantly 2.96 ($p < 0.05$) higher mean scores than snack SP3 and control (SP2) ($p < 0.05$). This could be due to the low proportion of OFSP (20%) and cassava (20%) in snack SP6, the malting of the maize and iron-rich beans, which could have given the snack a smooth texture. The findings of the current study are consistent with the findings of previous studies in which malting enhanced the textural quality and stickiness of a supplementary porridge and snacks made from a blend of cassava, maize, and sorghum by improving properties such as smoothness, binding, moisture retention and crispy texture while reducing off-tastes (Makame and Cronje, *et al.*, 2019). The study found that fat was significantly 59.76mg/100g ($p < 0.05$) higher in snack SP6 which had the highest score for mouthfeel mainly due to the creamy smoothness that makes the snacks moist and more palatable to the consumers (Syan *et al.*, 2024). This indicates that the higher preference for mouthfeel was most likely influenced by the high level of fat as documented by previous studies in development of cookies using cassava-grey speckled palapye blend (Austin *et al.*, 2021).

The study found that, SP3 and SP9 were most acceptable snacks (Table 7). This is not surprising considering the fact that snack SP3 and SP9 comprised very low cassava flour content, 5% and 0% respectively. This could have improved their flavor and taste compared to other snacks. The low score

for flavour in snack SP2 resulted into lower preference and acceptability. This suggests that the snack SP2 and SP3 had lower concentrations of secondary metabolites in the form of antinutrients, which are responsible for the bitter taste of foods (Adubofuor, Anomah & Amoah, 2018). However, taste of the snacks improved when the proportion of cassava flour was reduced in the snacks since cassava flour does not retain moisture well making the snacks to be crumbly therefore, when blended with other flours like maize, the moisture retention properties can be improved hence making the taste more appealing to the consumers (Susanto & Hartati, 2024).

In order to assess a product's general acceptability, the sensory properties of snacks must be evaluated to meet the targeted consumers' preferences, improve the product quality, ensure regulation and compliance, drive innovation, and minimize risks, to contribute to the success objectives of the product developed. The proximate and nutritional characteristics of the produced snacks are not, however, determined by these. In Section 5.2, the proximate and nutritional composition of the snacks made from cassava OFSP are discussed in depth. 5.2 Proximate and micronutrient composition of cassava-OFSP based snacks. The overall preference for the snacks were not significant ($p > 0.05$) due to the processing that resulting into snacks that were difficult to detect their uniqueness

5.2 Proximate composition of cassava-OFSP based snacks

The proximate composition of cassava-OFSP-based snacks is an important aspect to consider when evaluating the nutritional value of products (Owade *et al.*, 2018). Proximate composition refers to the amounts of macronutrients such as carbohydrates, proteins, and fats, as well as other components like moisture, fiber and ash (Chikpah *et al.*, 2020). With reference to the present study, the results in table 10 indicate snack SP5 had a significantly ($p < 0.05$) higher crude protein content than other snacks and that of control snack SP2. This is most likely in that formulation using many flours improves the overall bioavailability of the nutrients in the snacks flours like amaranth are rich in lysine which other flours do not have hence balanced protein composition. This increases the protein quality of the product and improves the availability of essential amino acids to the body (Sanya *et al.*, 2020). However, the crude

protein content in snack SP2 was higher than the protein content observed in snack SP3 similar to studies conducted for cassava based snack developed by Mosha *et al.*, (2010) most likely due to addition of ingredients like milk powder. Additionally, fermentation of cassava increased protein level in snack SP2 due to the enhanced digestibility promoted by microbes that are able to grow in the fermentation environment and therefore, may synthesize additional proteins (Afifah *et al.*, 2024).

The level of protein snack SP3 ($p>0.05$) compared to that in snack SP2 due to presence of phytate and tannins in amaranth and beans formed insoluble complexes with affecting bioavailability of protein and other nutrients (Mohanto & Aye, 2024), Furthermore, snack SP2 had higher protein than the level found in cassava (3.4g/100g) from eastern Uganda (Birungi *et al.*, 2023). This increase in protein could be due to the fermentation environment that resulted into build up *saccharomyces cerevisiae* bacteria to survive and carry out fermentation effectively (Pilajun & Wanapat, 2018). The current protein content in snack SP5 was in line with the previous studies which noted that use of 40% beans, 30% grains and 30% rice was responsible for the high level of protein as well as energy (Ndagire *et al.*, 2015). Snacks SP5, SP6 and SP9 made using composite flours have higher level of protein than control SP2 due to the addition of higher protein ingredients (iron rich beans and amaranth) which increased the overall protein content of snacks compared to that made using pure cassava. The level of crude protein in SP5 could also be due to the increasing temperature and time that was taken in the reduction of the antinutritional factors like phytate hence increased protein bioavailability similar to studies conducted on roasting of jack bean seeds (Odedeji *et al.*, 2019).

Furthermore, snack formulation SP3 developed using 80% OFSP flour had 18.37mg/100g of protein compared to snack SP2 developed using 100% cassava that had 20.6mg/100 protein despite cassava having between 1.4 to 2 mg/100g of protein. This variation in protein content was due to the high level (48.78mg/100g) of phytate in SP3 compared to only 1.52mg/100g phytate respectively. The high phytate level in SP3 reduced protein bioavailability by binding to the protein and minerals which could

humper digestion and assimilation of protein in this diet containing high levels of grains and legumes and could lead to lower protein utilization therefore protein nutrient deficiency.

This increased protein bioavailability in SP3 compared to that in SP9, structure and high moisture content of snack SP3 increased protein instability and degradation, resulting in a reduction in protein content (Rahaman *et al.*, 2016). The increased protein content of the cassava-based OFSP snack (SP5) may be attributable to the relatively higher proportion of sweet potatoes and beans used when compared to cassava. Furthermore, the observed increase in protein content during the study may also possibly be related to changes in the ash contents of malted maize and beans as a result of microbial activity knowing well that the nutrients in ash form part of protein structure (Olaniran *et al.*, 2020). This finding was in agreement with the findings that composite of cassava and wheat for making bread had higher moisture content than that of wheat alone and more prone to spoilage (Aondoaver *et al.*, 2021). This is because food components are hydrolyzed by malting into easier-to-use ones (Haile and Shufa, 2019). The findings of the present study are not unique as similar findings were reported elsewhere (Atuna *et al.*, 2021).

Crude fiber

Crude fiber contents in snack (SP3) were significantly higher than in snacks (SP9, SP5) and control snack (SP2) in Table 10. The higher crude fiber content of SP3 could be due to the high proportion of OFSP in the snack. This is in agreement with the previous studies which noted that the crude fiber in fermented and dried cassava was only 3.89% (Ismaila *et al.*, 2018). Similarly, the results do corroborate previous research, which showed that crude fiber in snacks increased with addition of OFSP flour (Temba *et al.*, 2017). This study finding is in agreement with that of previous studies in which cassava had 1.9 mg/100g of crude fiber compared to only 0.8 mg/100g for 100% cassava. This could be due to the effect of fermentation of cassava that was responsible for reduction of crude fiber in bitter cassava. Secondly the crude fiber increased significantly in snacks SP5 and SP6 with addition of more crude fiber, this is most likely due to sprouting of maize and beans that resulted in increase in crude, the

insoluble from maize while soluble one from bean flour altogether adding to the crude fiber of the snacks due to increased level from 3.78mg to 4.52 mg per 100g of crude fiber due to malting of NAROBan2 (Nfula. *et al.*, 2022) . Furthermore, snacks SP3 and SP9 have crude fiber content 6.43mg/100g and 5.25 mg/100g respectively which cannot potentially reduce nutrient bioavailability by forming insoluble complexes with nutrient like zinc, calcium and, iron (Birungi *et al* 2023). The study is similar to that conducted in Nigeria where crude fiber increased from 2.21% to 3.79% with the addition of OFSP flour to 'robo' (Onozare *et al.*, 2023). The results of the current study are not surprising considering that orange-fleshed sweet potatoes are an excellent source of dietary fiber that cannot be digested. Crude fiber, a non-digestible carbohydrates gives feces bulk, reduce intestinal transit time, lowers cholesterol levels, traps harmful cancer causing chemicals and promotes normal micro flora development in the gut flora in the gut (Chuwa *et al.*, 2020).Furthermore, snack SP6 had significantly higher crude fat than snacks SP3, SP9 and control (SP2).

Crude fat content

The high crude fat in snacks (SP6) compared to the level in control snack SP2 could be due to relatively higher fat content (0.1-0.2%) in OFSP roots and maize (3-4%) compared to cassava (0.2-0.5% (Neela, Satheesh, 2019). Similarly, the low fat (1.06%) in cassava in previous study was lower than that of the control used in the current study most likely due to addition of margarine as one of the additives (Ismaila *et al.*, 2018). As such, having more fat in any snack is beneficial because it provides the body with the greatest energy and aids in children's growth and development (Makori *et al.*, 2018). The results support those of Ojo and Akande (2013) who demonstrated that crude fat content increased as the level of OFSP incorporation increased.

Ash content

Furthermore, ash contents in control (SP2) was slightly higher than in other snack formulations (Table 10). Moreover, the entire mineral content of food is represented by the crude ash content, which implies

a higher mineral content in the 100% cassava snack. The high ash content in snack SP2 could be attributed to the endogenous hydrolysis of complex organic compounds present in the cassava during the fermentation process which released more nutrients like protein, fats and carbohydrates. The level of ash in snack SP2 could be due to the effect of fermentation that reduced the level of tannin and phytate antinutritional therefore increasing the bioavailability of minerals (Terefe et al., 2022). The study therefore noted that use of composite flour and single flours did not significantly increase the mineral content.

According to Ojo and Akande (2013) and (Atuna *et al.*, 2021), in their study found a rise in ash content with a higher degree of OFSP inclusion compared to a 100% cassava snack.

Formulation of snacks with addition of more flours reduced the level of ash in other snacks compared to snack SP2 which was in line with other findings by Omojokun *et al.*, (2021), but less than 2.01% in partially fermented and dried cassava flour as noted by Ismaila *et al.*, (2018).

Moisture content

In terms of moisture content, snack SP3 had significantly ($p < 0.05$) higher (12.37%) moisture content than control snack (SP2) as well as in snacks SP5 and SP9 that had 4.17% and 5.37% moisture respectively as shown in table 10. The increase in moisture content of snack SP3 may be due to the increased proportion of OFSP in the snack that naturally has high moisture content furthermore, this is in agreement with the findings that fermented and dried cassava contains 7.06% of moisture. The high moisture content between obtained in this study 5.37% and 12% in snacks SP9 and SP3 respectively, are in line moisture content ranging from 7.6% to 10.3% reported for NASPOT12 variety under dry matter condition (Ismaila *et al.*, 2018)..

The high moisture condition in snack SP3 makes it unsafe for feeding school children in primary school since this condition favors promote microbial growth and development and therefore, reduce the shelf life of the snacks by causing spoilage such as changes in snack texture, off-flavors, mold

growth, and in and production of toxic compounds like mycotoxins in some cases Atuna *et al.* (2019). This therefore implies that for cassava -OFSP-based snack, (SP3) to retain a long shelf life, the low moisture content is crucial. The highest proportion of OFSP in SP3 was 80%, indicating higher proportion of starch that has higher moisture affinity due amylopectin that swells and absorbs water as well as the hygroscopic properties of sugar that traps water but also presence of pectin in the cell wall retained moisture too. Any snack that contains a lot of moisture creates a favorable environment for microbial growth, which ultimately lowers food quality (Forsido *et al.*, 2021). This finding was in line with the studies which resulted in development of snacks, *kabalagala* using cassava and orange fleshed sweet potato (Adoko *et al.*, 2023). Other snacks containing more proportion of maize had an increase in the moisture content due to high water affinity for maize flour to absorb moisture from the surrounding into the snacks due to high level of starch and increased protein level in snacks (Sciarini *et al.*, 2010)

In summary, the analysis of the proximate composition of cassava OFSP – based snacks provide valuable insights into their functional properties and the potential benefits they offer in terms of nutrition. Therefore, incorporation of these ingredients into snack formulations can enhance the overall nutrient content and functionality of the products.

5.3 Micronutrient composition of cassava-OFSP based snacks

While snack products made from cassava and orange-fleshed sweet potatoes have gained popularity due to their potential nutritional benefits when processed (Abong' *et al.*, 2021). However, it is important to critically analyze the micronutrient composition of these snacks to fully understand their impact on overall dietary intake (Ertop & Bektaş, 2018). Micronutrient composition plays a critical role in maintaining healthy bodily functions. For instance, these micronutrients are essential for various chemical reactions, the structural formation of proteins, hormonal synthesis, immune function regulation, and overall growth and development (Wrottesley *et al.*, 2022).

5.3 Micronutrient content

The micronutrients that are considered in the current study are iron (Fe), zinc (Zn) and vitamin A to reduce the prevailing levels of micronutrient deficiencies among primary school children 6-15 years

Iron content

According to the results (Table 12), snack SP6 had a considerably greater iron content than snack SP3, SP5, SP9, and control (SP2) in the current study. Interestingly, compared to snacks SP3, SP5, SP6, and control (SP2), snack SP9 showed a considerably higher zinc content. The high proportion of NARO bean² in the snack formulas SP6 and SP9 might have had a significant impact on the amounts of vital nutrients like iron and zinc. This could have happened due to increased surface area enabled enzymes to modify the biochemical activity that increases the bioavailability of the micronutrient for use by the body (Kumar *et al.*, 2020).

Additionally, the malting process of the maize and NAROBAN² could have enabled the microbes to break down the macronutrients (protein and carbohydrates) to release vital nutrients like iron and zinc which were higher in snack SP3 and SP6 (Nafula *et al.*, 2022). The current study found a higher amount of iron compared to previous studies in Uganda, indicating that iron content of the snacks made with OFSP, amaranth seed, maize and iron-rich bean (Roba1) was 4.8 mg per 100 g (Natabirwa *et al.*, 2020). Similarly, a study by Tumuhimbise *et al.* (2018) in Uganda showed that the iron content ranged from 4.8 to 97.4 mg/100 g in snacks from mixtures of amaranth leaves and orange-fleshed sweet potatoes.

Zinc content

Furthermore, the level of iron and zinc in a snack mix made of amaranth seed, maize, orange-fleshed sweet potatoes, and iron-rich beans was 4.83 mg/100 g and 1.5 mg/100g, respectively, according to investigations by Natabirwa *et al.* (2020). The higher proportion of NAROBAN²

in the snack SP9 formulation could have increased the level of zinc coupled with the likelihood of zinc leaching from the pan into the snacks during baking process (Feitosa *et al.*, 2018). Furthermore, according to studies conducted by Brychkova *et al.*, (2020), the level of zinc could be high most likely due to the high ratio of phytate/zinc coupled with the uniform distribution of zinc in some grains like millet. Moreover, the implication of various micronutrients such as iron and zinc in disease management is well documented for instance, iron is crucial in oxygenating tissues and managing the processes of myelination and neurotransmission along with regulating the metabolism of neuronal energy via iron-containing enzymes (Kumari *et al.*, 2017). On the other hand, Zinc supports healthy organ growth and development and strengthens the immune system that maintain mental health and ensuring optimal cognitive functioning (Alowo *et al.*, 2018).

The importance of iron and zinc is further highlighted by the potential health risks associated with their deficiency to mention that of iron can lead to anemia most especially in children and women which is characterized by swollen legs, pale skin, fatigue, dizziness and spoon shaped nails and frequent infections are common among children in primary schools due to reduced intakes of nutritious foods among older children in primary schools (Harika *et al.*, 2017).

Vitamin A

The findings also show that snack formulation SP3 had a greater vitamin A content than snacks SP5, SP6, SP9, and the control (SP2). This is not surprising, as SP3 contained 80% OFSP in its formulation, which was much higher than the rest of the formulations. The high level of vitamin A in snack SP3 could be due to high moisture content in the snack that was responsible the retention of the nutrient (Momodu *et al.*, 2022). A similar trend was noted where β carotene value ranged between 345 and 370 $\mu\text{g}/100\text{ g}$ in 100% OFSP, but the content decreased slightly with the addition of maize flour (Sowa *et al.*, 2017).

According to Aderoju *et al.* (2020), noted that when quality protein maize flour was added to OFSP flour, there was an increase in β -carotene from 140 to 187 $\mu\text{g}/100\text{g}$ since OFSP is a high-quality source of carotenoids such as β -Carotene, a precursor of vitamin A (Lyabole *et al.*, 2024). Therefore, this could explain the high vitamin A content of snack SP3 which is essential for growth and development, mucus integrity, epithelial protection as well as healthy eyesight and, as such, numerous studies have suggested using it to address the VAD issues in poor nations Patil *et al.*, 2024). Inadequate intake of vitamin A in the diet of children leads to vitamin A deficiency that could cause night blindness in children. Therefore, the developed snacks from OFSP, cassava, maize, NAROBan2 and amaranth as evidenced in the current study, have the potential of providing adequate amounts of micronutrients such as zinc (3.38mg/100g to 717mg/100g), iron (18.8mg to 44.17mg/100g) and Vitamin A (812 $\mu\text{g}/100\text{g}$ to 1441.33 $\mu\text{g}/100\text{g}$) which are common deficiencies among school children in Sub-Saharan Africa due to reduced animal consumption (Cupertino *et al.*, 2022; Saffia, 2020; Praharaj *et al.*, 2021). This can result in having healthier pupils who are able to stay in school until the completion of the primary school cycle (Kajura *et al.*, 2020). However, to achieve this, parents education in the area of nutritional knowledge should be emphasized to enable them decide what their children should eat (Babatunde *et al.*, 2011). Therefore, the developed snacks can provide 67.6 to 143% of zinc for 100g serving, meanwhile 2039grams serving would provide 100% of zinc per days and 42 to 74 grams serving would provide 100% of the vitamin requirement per day.

Considering the nutritional requirement of children 6-15 years, snack SP3 is having phytate above the recommended lethal dosage of 25mg/100g and moisture content above 10% making it unsuitable for feeding school children (Mmbone *et al.*, 2023). Daily serving of snack SP6 to meet the RDA for children 6-8 years in terms of iron, zinc and vitamin A would need (22.7g , 66.5g and 38g) respectively. In addition, servings for children 9-13 years using SP9 would need 20g, 112g (boy and girls) 67g respectively for iron, zinc and vitamin A. Furthermore, to meet the RDA of iron, zinc and vitamin A for children 14 -18 years, servings of snack SP9 would need 27.3g (boys) and 37.3g (girls), 153.4g (boys) and 125.5g (girls), 80g (girls and 103g (girls) respectively. This analysis has been based on the preferences in that children 8-11 years preferred snacks with more OFSP proportions compared to the children 12-15 years who preferred snacks made of more maize and bean flours that were crunchy and had lighter colour.

5.4 Antinutritional factors in cassava and OFSP-based snacks

Antinutritional factors are compounds that reduce nutrient absorption or utilization in the body (Yang *et al.*, 2018). These antinutritional factors are in higher concentrations in legumes than any other plant based food. For instance, enzyme inhibitors, tannins, phytate, and lectins are among the commonly encountered antinutritional components in legumes.

Hydrogen cyanide

In relation to the present study, snack formula SP9 had the higher hydrogen cyanide as compared to the rest of the snack formula (Table 13). The higher hydrogen cyanide content could be attributed to traces of cyanide or cyanogenic glycosides, such as amygdalins and linamarin which are always present in some crops such as beans and maize (Abe *et al.*, 2015). Cyanogenic glucosides are a class of naturally occurring compounds that, upon hydrolysis, yield a sugar, an aldehyde or ketones and the extremely poisonous cyanide ion (Oloya *et al.*, 2018). The findings of the present study are consistent with previous research by Adejoh *et al.* (2020) which found high concentrations of cyanide in maize (250.00 ± 2.53 mg/kg) and beans (261.33 ± 3.51 mg/kg). Furthermore, the current study reports a higher hydrogen cyanide content level of 0.16 ± 0.00 mg/100g in some cassava-based snacks compared to that found during previous studies (Igbua *et al.*, 2020). However, the current study reports lower levels of hydrogen cyanide concentrations in snack SP9 than what was reported by Nwaichi *et al.*, (2013) in maize (0.5 mg/kg) and by Adeniran *et al.*, (2013), in lima beans (5.20 mg/kg) in Nigeria. Interestingly, no cyanide was detected in raw or processed maize during previous studies by Eleazu *et al.* (2020). The lower level of HCN in snack SP2 was most likely due to fermentation of bitter cassava that provided a conducive environment for microorganisms to secrete enzymes such as amylase, xylanase and linamarase that formed a hydrolytic bond with the cyanide compound and resulting into degradation of the compound (Adeleke *et al.*, 2017).

By implication, cyanide works as an irreversible inhibitor and therefore, stops the electrons in the electron transport chain of aerobic respiration from being transferred from cytochrome C oxidase to oxygen (Cierniecki & Newman, 2023). This has an impact on the ATP production needed for metabolism. If left unchecked, it might cause the muscle and nerve cells that depend on this kind of energy to gradually die and hence these could result in an individual's death (Ogbuagu *et al.*, 2019). Thus, precautionary detoxification by food processing methods should be emphasized for the snack formula with a high cyanide concentration in the present study. For example,

roasting and reduction in size of corn resulted in a notable reduction of the processed grain's cyanogenic glycoside concentration (Lumakin *et al.*, 2019).

Oxalate content

As far as the oxalate content of the cassava-OFSP snack is concerned, SP9 had higher proportions of oxalates than in all snacks used in the current study (Table 13), mainly due to high maize proportion in snack SP9. The findings of the present study reports a lower oxalate content than 7.0 mg/kg reported for sweet potato-cassava-based snacks (Olapade, and Ogunade, 2014) and 4.0 mg/kg in raw maize by Eleazu *et al.*, (2021). Although the oxalate level in SP3 is deemed high in the current study, it is far lower than the estimated 15–30 g/100g threshold that is fatal for humans (Lumakin *et al.*, 2019). Nevertheless, it should be remembered that consuming foods high in oxalate on a regular basis may prevent calcium absorption and increases the risks of developing kidney stones (Wang *et al.*, 2024). This results into loss of calcium leading to calcium deficiency disease like rickets in children leading to disorders in physical and mental developmental of osteoporosis which causes abnormal bones, large joints, and moving difficulty (Raskh, 2020).

Tannin content

The results further show that the tannin and polyphenol content of snack formula SP2 was significantly higher compared to the remaining snack formula (Table 14). For instance, tannin levels ranged from 0.98 mg/100 g in snack formula SP6 to 2.74 mg/100 g in snack formula SP2. These levels are higher than the range of 0.09–0.22% (Omah & Okafor, 2015), for cookies made from blends of millet-pigeon pea composite flour and cassava cortex compared to the levels from 0.00 mg/100g to 0.03 mg/100g for snacks developed using cocoyam Bambara groundnut flour blends (Bulus *et al.*, 2022). On the contrary, the findings of the current study do report lower tannin content in the cassava-OFSP based snack formula compared to previous studies which reported concentration of tannins in maize-based snacks to be 25 mg/100 g (Nagel, 2010), 3.5 mg/100 g (Maseta, & Mosha, 2016) and 3.62 to 6.09 mg/100 g for high- quality cassava-tigernut flour blends (Adebowale *et al.*, 2017). Snack SP9 formulated using composite flour had higher tannin content than other snacks SP3, SP5 and SP6 developed using more than one type of flour. This increase in the level of tannin in snack SP9 compared to other snacks due to the higher proportion of Iron Rich Beans used in snack since beans contain high level of tannin that can be reduced through malting (Nfula *et al.*, 2022) However, the level of tannin has been lower in this study due to leaching of tannin as a result of its high solubility in water which in line with other studies which

indicate reduced tannin between 0.194 and 0.464 per 100g in sorghum-soya processed by extrusion method (Kumar *et al.*, 2018).

This finding indicates that the low level of tannin in cassava reduced with increased age of the cassava plants but increase in tannin could be due to higher proportion of IRB flour that contains high level of tannins ranging from 23.67 to 36.97mg/100g using Oat-soybean and linseed blends which was higher than 0.98 to 2.76mg/100g in the current study (Duguma *et al.*, 2021). However, the level of tannin in SP6 is comparable to the 0.98 mg/100 g for pigeon pea and unripe plantain blend (Anuonye *et al.*, 2012). According to Nakitto *et al.* (2015), presence of tannins reduces protein, iron and zinc for bioavailability in the body due to formation of insoluble complexes. Indicating that tannins reduce the digestibility of proteins and absorption of micronutrients (Omah & Okafor, 2015). Therefore, future research should focus on the effect of traditional methods such as soaking in alkaline (Alkaline/Ash treatment) to reduce the level of tannin in cassava-OFSP based snack formula developed in the current study.

Polyphenol content

Furthermore, polyphenol concentration of 100% cassava flour (SP2) was higher than the rest of the developed snack formula. The results of this study are distinct from those of other studies, which showed that following the fermentation of the cassava composite flours, antinutritional components including phenols and oxalates decreased significantly (Digbeu *et al.*, 2013). The study found that polyphenol concentration was higher in SP2 snack formulated using 100% cassava and was greater than the 0.57–1.13 mg/100g phenolic content of cassava–tigernut flour blends as reported by Adebowale *et al.*, (2017). In contrast, the polyphenol content of the 100% cassava snack (SP2) in the present study is lower than that reported for cassava flour samples which ranged from 7.92 mg/100 g to 10.8 mg/100g (Nilusha *et al.*, 2021). Polyphenol compounds function as food preservatives by inhibiting the oxidation events that lead to food deterioration (Nilusha *et al.*, 2021; Rahman *et al.*,

2022). As a result, further studies could be conducted on antioxidant properties of cassava-based OFSP snacks developed in the present study.

Phytate content

Additionally, snack formula SP3, had significantly higher concentrations of phytates (48.78 mg/100 g) as compared to the remaining snack formula (Table 13). This can be due to high proportion of OFSP (80%) which could have contributed to the high amount of phytates in SP3 compared to other snack formula which had lower proportions of OFSP. These findings are comparable to previous study by Desalegn *et al.*, (2015) which found 40.0 mg/100 g of phytates content in 100% OFSP flours. In contrast, the phytate levels in SP3 are lower than the 200– 400 mg/100 g found in Orange-Fleshed Sweet Potato, soybean and carrots composite flours (Adetola *et al.*, 2020) and much less than 0.03 found in Micronutrient Dense Composite Flour (MDCF) lower than the lethal dosage of 25mg/100g reported by Mmbone *et al.*, (2023). A high phytate concentration in diet lowers the bioavailability of minerals such as iron, calcium, phosphorus, and zinc (Sanya *et al.*, 2020). This is a result of the formation of insoluble phytate mineral complexes with low bioavailability that can result into micronutrient deficiencies (Castro-Alba *et al.*, 2024).

Nonetheless, prior research unequivocally shows that conventional food processing methods, such as heating, soaking, and malting, among others, have the ability to reduce the antinutritional elements in composite flours, such as tannins, phytates, trypsin, and polyphenols, while simultaneously boosting nutrient bioavailability. For instance, previous study by Nafula *et al.* (2021) indicate that malting can significantly lower phytate in NARO Bean 2. Similar research from Tanzania shows that germination reduced the amount of phytic acid increased to 1.7% , 0.8% 0.7% in soy bean, ground beans and cowpea respectively (Abbas & Ahmad, 2021). Additionally, in order to increase mineral bioavailability as a result of feeding on snack SP3, it is advisable to take it along with food sources containing ascorbic acid to reduce formation of insoluble complexes with minerals such as iron (Zulfiqar *et al.*, 2024) Therefore, more research is needed to determine whether food processing techniques can successfully

lower the phytate concentration in SP3 and the other snack formulations, addressing the micronutrient inadequacies among the study area's school-age children.

Basing on the results in this study, it has been noted that addition of more flours can reduce significantly ($p < 0.05$) the levels of oxalates, tannin and moderately the hydrogen cyanide but did not significantly ($p > 0.05$) reduce the level of phytate due to addition of more phytate in beans in line with studies that indicated (0.92 – 1.22 mg/100g) in wheat soy and OFSP blend similar range in snack SP5 in the current study (Odiaka *et al.*, 2024).

CHAPTER SIX

CONCLUSION AND RECOMMENDATION

6.1 Conclusion

In conclusion, the formulation of snacks using composite flours processed from plant materials such as Orange Fleshed Sweet Potato NASPOT12 variety, local bitter cassava (*Nyarudota*), Longe 5 maize and yellow maize(50%) each, Amaranth seeds(*Hypochondriacus variety*) and NAROBAN2 variety. The flours formulated resulted in developed snacks that improved with addition of more flours in terms of their colour, flavour and mouthfeel but not chronologically. The different proportions of flours are suitable to be used in feeding of school children since they nutrient dense snacks with significant ($p<0.05$) increase iron, zinc and vitamin by 57.3, 47 and 43.6% in snacks SP6, SP9 and SP3 respectively. While, antinutritional factors were reduced below the recommended lethal dosages between 0.15mg/100g for polyphenols, Hydrogen cyanide (4.53mg/100g) being below the lethal dosage of 35mg/100g in snack SP9 which are generally below the lethal dosages (Udo *et al.*, 2018). However, the phytate level in snack SP3 is higher dosage of 2.78mg/100g above the lethal dosage of 2.78mg/100g therefore making it unsuitable for feeding school children due to risks of toxicity as reported by (Kiliobas *et al.*, 2019). This therefore, makes the snacks suitable sources of micronutrient to reduce the deficiencies among school children 6-15 years especially in rural communities of Zombo District. The snacks were generally liked by the 130 pupils who participated in the sensory evaluation resulting in the selection of three snacks, SP3, SP6 and SP9.

However, the study noted the highest moisture content in snack SP3 (12.37%) yet the maximum recommended moisture content to provide safe and healthy snacks is 10% (Herdeiro *et al.*, 2024). The prioritized snacks were SP9 and SP6 were the snacks suitable for feeding school children 6-15 years and would provide nutritional quality and making the snacks safer for feeding school children therefore improved bioavailability of nutrients making the snacks suitable to reduce micronutrient deficiencies of iron zinc and vitamin A among school children.

The development of school snacks tailored to meet the nutritional needs of children presents a promising strategy for combating malnutrition, improving academic performance, and fostering healthier communities. By addressing both nutritional adequacy and cultural acceptability, these snacks have the potential to be both an effective and sustainable solution in school feeding programs.

6.2.2 Recommendation

For universities

1. Further studies should be conducted by interested researchers to investigate the effect of traditional processing methods such as soaking, roasting and malting on the proximate and nutritional composition of the cassava-OFSP snack formulations after this recommendations.
2. Other students could evaluate bioavailability of water soluble nutrients like iron, zinc and vitamin due to soaking, roasting, and malting processes used during the development of the cassava-OFSP snack formulations using in Vitro method such as Simulated Gastrointestinal Digestion (SGD Method).
3. Interested students or universities could investigate the shelf life of the snacks using chemical and physical analysis method to detect specific changes overtime such as oxidation, moisture variation and nutrient degradation.

For departments

4. The study could be incorporated to build up on the Uganda Multi sectoral food security and nutrition programme, under the ministry of Agriculture Animal Industry and Fisheries (MAAIF) that builds emphasis on Orange Fleshed Sweet potato and Iron Rich Beans among others.
5. The office of the prime minister and ministry of education could investigate using sensory analysis the possibility of utilizing the formulations in this study in form of porridge for feeding children and women who are generally at higher risks when a disasters occurs as well as school children. This could be done as soon as possible with support from Gulu University.

7. Other students could compare the use of NAROBan1 and NAROBan2 on the effects on bioavailability of nutrients such as iron, zinc and vitamin A using nutrient interaction study with the antinutritional factors like phytate.

For food processors

Food processing companies could conduct studies on microbial growth especially in snack SP3 that had moisture the highest moisture content of 12.37% suitable for microbial growth. This could be investigated using Polymerase Chain Reaction (PCA) to detect and quantify DNA microbial counts that are relevant in detecting foodborne pathogens like Salmonella, E.coli

9. The food processor could also investigate the effects of using silver fish instead of amaranth flour used in the formulation of snacks in the current study using fermentation and enzyme treatment to improve the nutritional content and therefore increased bioavailability for feeding school children.

For Local Governments

10. Small scale processing plants could be established by schools to train parents and pupils on how to develop snacks for feeding the school children

REFERENCES

- Abass, W. A. and E. O. A. (2019). Assessment of the chemical and trace metal composition of dried cassava products from Nigeria Abstract. *Quality Assurance and Safety of Crops & Foods*, 11(1), 43–52.
- Abbas, Y., & Ahmad, A. (2018). “Impact of processing on Nutritional and Antinutritional Factors.” *Food Science and Technology*, 19:(2), 199–215.
- Abdoulaye, T., Olivier, K. K. J., Alioune, C., Sidikiba, S., Alexandre, D., Emmanuel, K. Y., Koolo, B. I., Sory, D. I., Falaye, T., Bangaly, M. F., Nagham, K., Diao, C., Laurent, A. A., Cécile, C., Francois, E. J., & Pathé, D. M. (2018). "Prevalence and Determinants of Malnutrition Among Schoolchildren in Primary Schools in the Communes of ". *African Journal of Public Health*, 4(2), 38–47.
- Abe, N., Kasuga, S., Okabe, M., & Goto, T. (2015). Single laboratory method validation for cyanide in beans with insufficient levels of β -glucosidase activity. *Quality Assurance and Safety of Crops and Foods*, 7(4), 501–507.
- Abong', G. O., Muzhingi, T., Okoth, M. W., Ng'ang'a, F., Emelda Ochieng, P., Mbogo, D. M., Malavi, D., Akhwale, M., & Ghimire, S. (2021). Processing methods affect phytochemical contents in products prepared from orange-fleshed sweetpotato leaves and roots. *Food Science and Nutrition*, 9(2), 1070–1078.
- Acham, Hedwig, Kikafunda JK2, T. T. and M. M. (2012). Nutritional and Health status of primary school children in Uganda. *African Journal of Food Agriculture Nutrition and Development*, 12(2).
- Achouri, I., Aboussaleh, Y., Sbaibi, R., & Ahami, A. (2021). Anthropometry, food consumption and iron deficiency anemia, among primary school children (6-15 years) in kenitra city (north-western morocco). *Pan African Medical Journal*, 38.
- Adamu-Governor, L. O., Adebayo-oyetoro, A. O., & Ofodile, N. (2015). Macronutrients and Micronutrients Profile of Some Underutilized Beans in Macronutrients and Micronutrients Profile of Some Underutilized Beans in South Western Nigeria. *International Journal of Biochemistry Research*, 7(2), 80–89.
- Adebayo-oyetoro, A. O., Olatidoye, O. P., Bamikole, T. J., Igene, C. O., & Coker, O. J. (2021). Quality Characteristics of Complementary Food from Locally Fermented Maize Flour Blended with Sprouted Velvet Bean (*Mucuna utilis*) Flour in Nigeria. *European Journal of Nutrition & Food Safety*, 13(1), 79–92.
- Adebisi, O. A., Adebisi, L. O., Olantunji, I. B., Daodu, T. O., Omofaiye, A. M., & Akilapa, O. A. (2020). Sensory Evaluation and Willingness To Pay for Orange Flesh Sweet Potato. *Cercetari Agronomice in Moldova*, 53(1), 73–83.
- Adebowale, A. A., Kareem, S. T., Sobukola, O. P., Adebisi, M. A., Obadina, A. O., Kajihansa, O. E., Adegunwa, M. O., Sanni, L. O., & Keith, T. (2017). Mineral and Antinutrient content of High Quality Cassava-Tingernut Composite Floiur Extruded Snack. *Journal of Food Processing and Preservation*, 41(5), e13125.

- Adeleke, B. S., Akinyele, B. J., Olaniyi, O., & Jeff-Agboola, Y. (2017). Effect of Fermentation on Chemical Composition of Cassava Peels mannanase production View project Mushroom Enrichment View project. *Asian Journal of Plant Sciences*, 7(4), 31–38. www.pelagiaresearchlibrary.com
- Adeniran, H. A., Farinde, E. O., & Obatolu, V. A. (2013). Effect of Heat Treatment and Fermentation on Anti-Nutrients Content of Lima Bean (*Phaseolus lunatus*) During Production of Daddawa Analogue. *Annual Review & Research in Biology*, 3(3), 256–266.
- Aderibigbe, O. R., Ezekiel, O. O., Owolade, S. O., Korese, J. K., & Sturm, B. (2020). Exploring the potentials of underutilized grain amaranth (*Amaranthus* spp .) along the value chain for food and nutrition security : A review. *Critical Reviews in Food Science and Nutrition*, 0(0), 1–14.
- Aderibigbe, O. R., Ezekiel, O. O., Owolade, S. O., Korese, J. K., & Sturm, B. (2022). Exploring the potentials of underutilized grain amaranth (*Amaranthus* spp .) along the value chain for food and nutrition security : A review. *Critical Reviews in Food Science and Nutrition*, 62(3), 656–669. <https://doi.org/10.1080/10408398.2020.1825323>
- Aderoju, A., Dorcas, A., Olayioye, O., Adedolapo, A., Babatunde, O., & Olunlade, A. (2020). Quality characteristics of biscuits prepared from composite flour of yellow fleshed cassava and quality protein maize. *Faculty of Food and Engineering*, 12(4), 297–306.
- Adesanmi, A. R., Malomo, S. A., & Fagbemi, T. N. (2020). “Nutritional quality of formulated complementary diet from defatted almond seed , yellow maize and quality protein maize flours.” *Food Production, Processing and Nutrition*, 7:(4), 4–12.
- Adigwe, N. E., Kiin-kabari, D. B., & Emelike, N. J. T. (2023). Nutritional Quality and In vitro Protein Digestibility of Complementary Foods Formulated from Maize , Cowpea and Orange-Fleshed Sweet Potato Flours : A Preliminary Study. *Asian Food Science Journal Volume*, 22(2), 25–37.
- Adoko, M. C., Olum, S., Elolu, S., & Ongeng, D. (2023). Addition of Orange-Fleshed Sweet Potato and Iron-Rich Beans Improves Sensory, Nutritional and Physical Properties But Reduces Microbial Shelf Life of Cassava-Based Pancake (Kabalagala) Designed for Children 2-5 Years Old. *Journal of Culinary Science and Technology*, 21(2), 173–197. <https://doi.org/10.1080/15428052.2021.1911899>
- Adubofuor, J., Anomah, J. W., & Amoah, I. (2018). Anti - nutritional factors and mineral composition of pumpkin pulp and functional properties of pumpkin - wheat composite flour for bread preparation. *International Journal of Innovative Food Science and Technology*, 1(1), 1–9.
- Akande, O. A., Nakimbugwe, D., & Mukisa, I. M. (2017). Optimization of extrusion conditions for the production of instant grain amaranth- - based porridge flour. *Food Science & Nutrition*, 6, 1205–1214.
- Akin-idowu, P. E., Odunola, O. A., Michael, A., Ademoyegun, O. T., Aduloju, A. O., & Olagunju, Y. O. (2017). Nutritional Evaluation of Five Species of Grain Amaranth – An Underutilized Crop. *International Journal of Sciences*, 6(01:), 2410–4477.
- Akram, M., & Idrees, M. (2019). Progress and prospects in the management of kidney stones and developments in phyto-therapeutic modalities. *International Journal of Immunopathology and Pharmacology*, 33, 1–5.

- Alam, M. K., & Islam, Z. H. R. and S. N. (2016). Comparison of the Proximate Composition , Total Carotenoids and Total Polyphenol Content of Nine. *MDPI*, 5(64).
- Alamu, B. M. E. O., Popoola, I. O., & Yomeni, M. (2017). Nutritional and sensory properties : Snack food made from quality cassava flour and legume blend. *Food Science & Nutrition*, 5(1), 805–811. <https://doi.org/10.1002/fsn3.464>
- Alamu, E. O., Maziya-dixon, B., Ntawuruhunga, P., & Chikoye, D. (2020). Evaluation of nutritional properties of cassava-legumes snacks for domestic consumption — Consumer acceptance and willingness to pay in Zambia. *Agriculture and Food*, 5(3), 500–520.
- Alamu, E. O., Maziya-dixon, B., & Olaniyan, B. (2020). Evaluation of nutritional properties of cassava-legumes snacks for domestic consumption — Consumer acceptance and willingness to pay in Zambia Evaluation of nutritional properties of cassava-legumes snacks for domestic consumption — Consumer acceptance an. *AIMS Agriculture & Food*, 5(3), 500–520.
- Alamu, E. O., Maziya-Dixon, B., Olaniyan, B., Pheneas, N., & Chikoye, D. (2020). Evaluation of nutritional properties of cassava-legumes snacks for domestic consumption-consumer acceptance and willingness to pay in Zambia. *AIMS Agriculture and Food*, 5(3), 500–520.
- Alemayehu, F. R., Bendevis, M. A., & Jacobsen, S. (2014). The Potential for Utilizing the Seed Crop Amaranth (*Amaranthus* spp .) in East Africa as an Alternative Crop to Support Food Security and Climate Change Mitigation. *Agronomy and Crop Science*. <https://doi.org/10.1111/jac.12108>
- Aliyar, Ruzky, A. G. and H. (2015). A review of nutritional guidelines and menu compositions for school feeding programs in 12 countries. *Frontiers in Public Health*, 3(148), 1–13.
- Alowo, D., Muggaga, C., & Ongeng, D. (2018). The effect of traditional malting technology practiced by an ethnic community in northern Uganda on in-vitro nutrient bioavailability and consumer sensory preference for locally formulated complementary food formulae. *Food Science and Nutrition*, 6(10), 2491–2498.
- Aly, M. M. A., & Seleem, H. A. (2015). Gluten-Free Flat Bread and Biscuits Production by Cassava , Extruded Soy Protein and Pumpkin Powder. *Food and Nutrition*, 6(1), 660–674.
- Anaemene Di, F. G. (2020). Effect of Fermentation , Germination and Combined GerminationFermentation Processing Methods on the Nutrient and Anti-nutrient Contents of Quality Protein Maize (QPM) Seeds. *Appl. Sci. Environ. Manage.*, 24(9), 1625–1630.
- Andama, M., & Oloya, B. (2017). Effectiveness of Traditional Processing Techniques in Reducing Cyanide Levels in Selected Cassava Varieties in Zombo District , Uganda. *International Journal of Food Science and Biotechnology*, 2(4), 121–125.
- Aondoaver, A. S., Praie, A. J., Omolola, A. J., & Oshiapi, I. P. (2021). “Physical and Microstructural Properties of Composite Cassava-wheat Bread Produced from Blend of Wheat and Low Postharvest Physiological Deterioration Cassava Flours.” *American Journal of Food Science and Technology*, 9(4), 142–148.
- Arisa, N., Adelekan, A., Alake, O., & Anaemene, D. (2021). Proximate , Microbiological and Sensory Properties of Cookies Made from Blends of African Pear (*Darcryodes edulis*) and Yellow Maize (*Zea mays*) Flours. *Journal of Science and Technology Research*, 3(1), 72–82.
- Arribas, C., Cabellos, B., Cuadrado, C., Guillam, E., & Pedrosa, M. M. (2019). Sensory Analysis of Rice-Based Extruded Snacks-Like Fortified with Bean and Carob Fruit Flours. *MDPI*, 8.

- Asiki, G., Newton, R., Marions, L., & Kamali, A. (2019a). The effect of childhood stunting and wasting on adolescent cardiovascular diseases risk and educational achievement in rural Uganda : a retrospective cohort study. *Global Health Action*, 12(1). <https://doi.org/10.1080/16549716.2019.1626184>
- Asiki, G., Newton, R., Marions, L., & Kamali, A. (2019b). The effect of childhood stunting and wasting on adolescent cardiovascular diseases risk and educational achievement in rural Uganda : a retrospective cohort study. *Global Health Action*, 12(1). <https://doi.org/10.1080/16549716.2019.1626184>
- Assemie, M. A., Alamneh, A. A., Ketema, D. B., Adem, A. M., Desta, M., Petrucka, P., & Ambaw, M. M. (2020). High burden of undernutrition among primary school-aged children and its determinant factors in Ethiopia ; a systematic review and meta-analysis. *Italian Journal of Pediatrics*, 46, 1–14.
- Atlaw, T. K. (2020). Influence of Drying Methods on Flour Quality and Cyanide Content of Cassava Root Tuber. *International Journal of Nutrition and Food Science*, 7(4), 142–147.
- Atuna, R. A., Ametei, P. N., Bawa, A. A., & Amagloh, F. K. (2021). Traditional processing methods reduced phytate in cereal flour, improved nutritional, functional and rheological properties. *Scientific African*, 15(12), 1–10. <https://doi.org/10.1016/j.sciaf.2021.e01063>
- Aurelie Solange, Agume, N., Yanou, N., Mbofung, N., & F., C. M. (2017). Effect of Soaking and Roasting on the Physicochemical and Pasting Properties of Soybean Flour. *MDPI*, 6(12), 8–17.
- Austin, I., Chidinma, I., Canice, K., & Obinna, O. (2021). Production and Quality Evaluation of Cookies Using Cassava-Grey Speckled Palapye Cowpea Composite Flour. *Asian Food Science Journal*, 20(11), 13–22.
- Awolu, O. O., & Akintade, A. O. (2021). Optimisation of Rice-Kidney Beans Composite Flours Incorporated with Fermented and Unfermented Sorghum Flours for the Production of Ready-to-Eat Extruded Snacks. *Asian Food Science Journal*, 20(4), 1–21.
- Azene, H., & Molla, T. (2017). Nutritional Composition and Effects of Cultural Processing on Anti-nutritional Factors and Mineral Bioavailability of Colocasia Esculenta (Godere) Grown in Wolaita Zone , Ethiopia. *Journal of Food and Nutrition Sciences* 2017;, 5(4), 147–154. <https://doi.org/10.11648/j.jfns.20170504.12>
- Babatunde, R. O., Olagunju, F. I., Fakayode, S. B., & Foluke Eunice Sola-Ojo. (2011). Prevalence and Determinants of Malnutrition among Under-five Children of Prevalence and Determinants of Malnutrition among Under-five Children of Farming Households in Kwara State , Nigeria. *Journal of Agricultural Sciences*, 3(3), 173–181.
- Badiu, A., & Babawande, A. O. (2020). Quality Characterization of Complementary Food Produced from Orange Flesh Sweet Potato Supplemented with Cowpea and Groundnut Flour. *Journal of Food Stability*, 3(2), 90–104.
- Banwo, K., Tosin Ojetunde, J., & Falade, T. (2023). Probiotic and Cyanide Degrading Potentials of *Pediococcus Pentosaceus* and *Pichia Exigua* Isolated from Cassava Products Effluent. *Food Biotechnology*, 37(1), 1–24. <https://doi.org/10.1080/08905436.2022.2163252>
- Bao, Badi M. and Fweja, L. W. T. (2020). Nutritional and sensory quality of orange-fleshed sweet potato varieties. *Annals.Food Science and Technology*, 21(3), 560–567.

- Bechoff, Taleon, Carvalho, C. (2017). Micronutrient (Provitamin A and Iron/Zinc) Retention in Biofortified Crops. *African Journal of Food Agriculture, Nutrition and Development*, 17(2), 11893–11904.
- Beintema, J. J. S., Luis, S. G., & Talsma, J. R. E. F. (2018). Scaling- up biofortified beans high in iron and zinc through the school- feeding program: A sensory acceptance study with schoolchildren from two departments in southwest Colombia. *Food Science and Nutrition*, 2, 1138–1145.
- Bekidusa, A., & Kisimbii, J. (2020). Influence of School Feeding Program on the Retention of Learners in Public Primary Schools in Kenya ; A Case of Mombasa County. *Education and Practice*, 4(3), 1–12.
- Bello, F. A., & Udo, J. A. (2018). Effect of processing methods on the nutritional composition and functional properties of flours from white and yellow local maize varieties. *Journal of Advances in Food Science & Technology*, 5(1), 1–7.
- Beniwal, S. K., Devi, A., & Sindhu, R. (2019). Effect of grain processing on nutritional and physico-chemical, functional and pasting properties of amaranth and quinoa flours. *Indian Journal of Traditional Knowledge*, 18(3), 500–507.
- Beta, T., & Taeyoung, H. (2018). Influence of heat and moisture treatment on carotenoids, phenolic content, and antioxidant capacity of orange maize flour. *Food Chemistry*, 246(10), 58–64.
- Bighaghire, R., Okidi, L., Muggaga, C., & Ongeng, D. (2020). “Traditional vegetable preservation technologies practiced in Acholi subregion of Uganda improves mineral bioavailability but impacts negatively on the contribution of vegetables to household needs for micronutrients.” *Food Science and Nutrition*, 9(5), 589–604.
- Brychkova, G., Gallego, S., Raatz, B., & Spillane, C. (2020). When Preparing Common Household Recipes. *Nutrients*, 12(658), 1–18.
- Buzigi, E., Pillay, K., & Siwela, M. (2020). Effect of cooking locally available common bean (Obwelu) on iron and zinc retention, and pumpkin (Sweet cream) on provitamin A carotenoid retention in rural Uganda. *Food Science and Nutrition*, 8(11), 5916–5925.
- Byarugaba, R., Nabubuya, A., & Muyonga, J. (2020). Descriptive sensory analysis and consumer preferences of bean sauces. *Food Science & Nutrition*, 8, 4252–4265.
- Byaruhanga, L. A., Masinde, D. M., Nonnecke, G. R., Lutwama, D., Kimiywe, J., & Nyangaresi, D. M. (2017). Effect of School Garden Food Production on Nutrient Adequacy of School Meals for Children Attending Namasagali Primary School in Rural Kamuli District, Uganda. *International Journal of Food Science and Nutrition*, 2(4), 114–118.
- Chauhan, A., Saxena, D. C., & Singh, S. (2015). LWT - Food Science and Technology Total dietary fibre and antioxidant activity of gluten free cookies made from raw and germinated amaranth (*Amaranthus spp.*) flour. *LWT - Food Science and Technology*, 63(2), 939–945. <http://dx.doi.org/10.1016/j.lwt.2015.03.115>
- Chauhan, N., Chaudhary, V., & Singh, B. (2019). Effect on Crude Fibre, Iron and Calcium Content of Multi Flour Noodles during Storage. *International Journal of Current Microbiology and Applied Sciences*, 8(04), 1302–1307.
- Chikpah, S. K., Korese, J. K., Hensel, O., & Sturm, B. (2020). Effect of Sieve Particle Size and Blend Proportion on the Quality Properties of Peeled and Unpeeled Orange Fleshed Sweet Potato Composite Flours. *MDPI*, 9(6), 1–22.

- Christopher Delgado. (2019). *The Cassava Value Chain In Mozambique*. 31.
- Chuwa, C., Metab, N., Acc, O., Science, F., & Pradesh, H. (2020). Food Fibres: A Solution to Combat Non-Communicable Diseases. *Nutrition and Metabolism: An Open Access*, 2018(01).
- Comandini, O., Cabras, S., Ssensamba, J. T., Bukenya, J. N., Cipriano, A., Carmignani, G., Carmignani, G., & Marini, E. (2019). Nutritional status of Ugandan school-children : The effect of age imprecision. *American Journal of Physical Anthropology*, 170(6), 88–97. <https://doi.org/10.1002/ajpa.23895>
- Cupertino, A., Ginani, V., Cupertino, A. P., & Braz, R. (2022). School Feeding Programs : What Happens Globally ? *International Journal of Environmental Research and Public Health*, 19.
- Daba, M. (2021a). Nutritional And Hydrogen Cyanide Compositions And Consumers Preference In Cassava Varieties Grown In East Hararghe Zone Of Oromia , Ethiopia. *International Journal of Science & Technology Research*, 8(2), 2277–8616.
- Daba, M. (2021b). Nutritional And Hydrogen Cyanide Compositions And Consumers Preference In Cassava Varieties Grown In East Hararghe Zone Of Oromia , Ethiopia. *International Journal of Scientific & Technology Research*, 8(2).
- Dako, E., Retta, N., & Desse, G. (2016). Comparison of Three Sweet Potato (*Ipomoea Batatas* (L.) Lam) Varieties on Nutritional and Anti-Nutritional Factors. *Global Journal of Science Frontier Research: D Agriculture and Veterinary*, 16(4).
- Daniel, Bulus, S., Nkama, I., & Esther, O. C. (2022). Effect of Processing on the Antinutrient Content of Extruded Snacks from Cocoyam – Bambara Groundnut Flour Blends. *Asian Food Science Journal*, 21(9), 19–27.
- Deming, D. M., Reidy, K. C., Fox, M. K., Briefel, R. R., Jacquier, E., & Eldridge, A. L. (2017). Cross-sectional analysis of eating patterns and snacking in the US Feeding Infants and Toddlers Study 2008. *Public Health Nutrition*, 20(9), 1584–1592.
- Desalegn, B. B., Abegaz, K., & Kinfe, E. (2015). Effect of Blending Ratio and Processing Technique on Physicochemical Composition , Functional Properties and Sensory Acceptability of Quality Protein Maize (QPM) Based Complementary Food. *International Journal of Food Science and Nutrition Engineering*, 5(3), 121–129.
- Dewidar, O. M., & El, H. M. A. (2020). Development of extruded snacks and corn flakes using yellow corn and by-product broken beans. *Middle East Journal of Applied Sciences*, 10(2), 390–406.
- Digbeu, D. Y., Due, A. E., & Dabonne, S. (2013). Biochemical characteristics of composite flours: Influence of fermentation. *Food Science and Technology*, 33(4), 599–604. <https://doi.org/10.1590/S0101-20612013000400001>
- Duguma, H. T., Forsido, S. F., & Belachew, T. (2021). Changes in Anti-nutritional Factors and Functional Properties of Extruded Composite Flour. *Frontiers in Sustainable Food Systems*, 5(11), 1–11.
- Eleazu, C. O., Eleazu, K. F., Ukamaka, G., Adeolu, T., Ezeorah, V., Ezeorah, B., Ituma, C., & Ilom, J. (2021). Nutrient and Antinutrient Composition and Heavy Metal and Phenolic Profiles of Maize (*Zea mays*) as Affected by Different Processing Techniques. *ACS Food Science and Technology*, 1(1), 113–123.

- Eloolu, S., & Ongeng, D. (2020). Approach to address short-term hunger and undernutrition among primary school children in rural areas in a developing country setting : lessons from North and North-Eastern Uganda. *BMC Nutrition*, 6(73), 1–10.
- Emilie, J., Mbassi, G., Alban, N., Bertrand, Z. Z., Mikhail, A., & Bogweh, N. E. (2022). Nutritional, organoleptic, and physical properties of biscuits made with cassava flour: effects of eggs substitution with kidney bean milk (*Phaseolus vulgaris* L .). *International Journal of Food Properties*, 25(1), 695–707. <https://doi.org/10.1080/10942912.2022.2058014>
- Ertop, M. H., & Bektaş, M. (2018). Review Article Enhancement of Bioavailable micronutrients and Antinutrients in foods with some processes Antinutrients in Foods. *Food and Health*, 4(3), 159–165.
- Ezeokeke, C. T., & Onuoha, A. B. (2016). Nutrient Composition of Cereal (Maize), Legume (Soybean) and Fruit (Banana) as a Complementary Food for Older Infants and Their Sensory Assessment. *Journal of Food Science and Engineering*, 6, 139–148.
- Fanta, S. W. (2019). Review on nutritional composition of orange - fleshed sweet potato and its role in management of vitamin A deficiency. *Food Science and Nutrition*, January, 1920–1945. <https://doi.org/10.1002/fsn3.1063>
- Feitosa, S., Greiner, R., Meinhardt, A. K., Müller, A., Almeida, D. T., & Posten, C. (2018). Effect of traditional household processes on iron, zinc and copper bioaccessibility in black bean (*Phaseolus vulgaris* L.). *Foods*, 7(8), 1–12.
- Fikiru, O., Bultosa, G., Forsido, S. F., & Temesgen, M. (2016). Nutritional quality and sensory acceptability of complementary food blended from maize (*Zea mays*), roasted pea (*Pisum sativum*), and malted barley (*Hordium vulgare*). *Food Science & Nutrition*, 5(2), 173–181.
- Folorunso, A. A., & Ojo, A. O. (2021). Evaluation of iron-rich snacks using liver powder and wheat flour blends for Women of reproductive age. *Journal of Current Research in Food Science*, 2(1), 12–18.
- Forsido, S. F., Welelaw, E., Belachew, T., & Hensel, O. (2021). Effects of storage temperature and packaging material on physico-chemical, microbial and sensory properties and shelf life of extruded composite baby food flour. *Heliyon*, 7(4), e06821. <https://doi.org/10.1016/j.heliyon.2021.e06821>
- Fronteras, J. P., Malida, P. L. S., Lumakin, C. L. U., Villame, R. G. E., Alviola, P. A., Alpos, M. A., & Lorilla, A. P. (2019). Effect of indigenous processing on the nutrient and antinutrient content of corn (*Zea mays* L.). *Philippine Journal of Science*, 148(1), 179–183.
- Fungo, R. (2017). Variation of β -Caroten , Zinc and Iron in different Banana (*Musa Spp* .) Accessions *β -Caroten , Zinc and Iron in DIFFERENT BANANA (MUSA Spp .) ACCESSIONS*. January 2008.
- Fungo, R. (2023). Implementation of the school feeding and nutrition programmes in Uganda and the contribution of school meals to recommended dietary allowances (RDAs) of children : Challenges and opportunities. *African Journal of Food Science*, 17(5), 85–101.
- Gawande, A. V., & Babar, K. P. (2018). Effect of Malting & Fermentation on the Functional & Rheological Properties of Sorghum Flour. *Asian Food Science Journal*, 1(1), 1–4.

- Gi, O., Kt, S., & Bo, A. (2018). Production and Quality Evaluation of Maize Chips (Kokoro) Produced from Maize and Whole Limabean Seed Flour Blends. *Advancement in Food Technology*, 1(1), 1–7.
- Glahn, R. P., Wiesinger, J. A., & Lung, M. G. (2020). Iron Concentrations in Biofortified Beans and Nonbiofortified Marketplace Varieties in East Africa Are Similar. *Journal of Nutrition*, 150, 3013–3023.
- Glahn, R., Tako, E., Hart, J., Haas, J., Lung, M., & Beebe, S. (2017). Iron Bioavailability Studies of the First Generation of Iron-Biofortified Beans Released in Rwanda. *MDPI*, 9.
- Godrich, J., Rose, P., & Gould, J. (2023). Original article The effect of popping , soaking , boiling and roasting processes on antinutritional factors in chickpeas and red kidney beans. *International Journal of Food Science and Technology*, 58(9), 279–289.
- Gomes, G. V. L., Sola, M. R., Marostegan, L. F. P., Jange, C. G., Cazado, C. P. S., Pinheiro, A. C., Vicente, A. A., & Pinho, S. C. (2017). Physico-chemical stability and in vitro digestibility of beta-carotene-loaded lipid nanoparticles of cupuacu butter (*Theobroma grandiflorum*) produced by the phase inversion temperature (PIT) method. *Journal of Food Engineering*, 192, 93–102.
- Green, M., Dreyfuss, M. L., Izwardy, D., Huffman, S. L., Hadihardjono, D. N., & Foundation, M. G. (2019). Commercially produced complementary foods in Bandung City , Indonesia , are often reported to be iron fortified but with less than recommended amounts or suboptimal forms of iron. *Maternal & Child Nutrition*, 15(1), 1–10.
- Gupta, M., & Bansal, V. (2021). Development of gluten free snacks using chickenpea flour and Flax seeds. *Journal of Emerging Technologies and Innovation Research(JETIR)*, 8(10).
- Gurmua, F., And, S. H., & Laing, M. (2017). Evaluation of candidate orange-fleshed sweetpotato clones for nutritional Acta Agriculturae Scandinavica , Section B — Soil & Plant Evaluation of candidate orange-fleshed sweetpotato clones for nutritional traits. *Acta Agriculturae Scandinavica, Section B Soil & Plant Science*, 10(4), 1651–1913.
- Haile, A., & Getahun, D. (2018). Evaluation of Nutritional and Anti Nutrition Factors of Orange-fleshed Sweet Potato and Haricot Bean Blended Mashed Food for Pre-school Children : The Case of Dale. *Food Science and Technology*, 6(1), 10–19.
- Haile, A., & Getahun, D. (2020). Evaluation of Nutritional and Anti Nutrition Factors of Orange-fleshed Sweet Potato and Haricot Bean Blended Mashed Food for Pre-school Children : The Case of Dale. *Food Science and Technology*, 6(1), 10–19.
- Haile .R, A., & Getahun, D. (2020). Evaluation of Nutritional and Anti Nutrition Factors of Orange-fleshed Sweet Potato and Haricot Bean Blended Mashed Food for Pre-school Children : The Case of Dale. *Food Science and Technology*, 6(1), 10–19.
- Harika, R., Faber, M., Samuel, F., Mulugeta, A., Kimiywe, J., & Eilander, A. (2017). Are Low Intakes and Deficiencies in Iron, Vitamin A, Zinc, and Iodine of Public Health Concern in Ethiopian, Kenyan, Nigerian, and South African Children and Adolescents? *Food and Nutrition Bulletin*, 38(3), 405–427.
- Honi, B., Mukisa, I. M., & Mongi, R. J. (2017a). Proximate composition, provitamin A retention, and shelf life of extruded orange-fleshed sweet potato and bambara groundnutbased snacks. *Journal of Food Processing and Preservation*, 11

- Honi, B., Mukisa, I. M., & Mongi, R. J. (2017b). Proximate composition, provitamin A retention , and shelf life of extruded orange-fleshed sweet potato and bambara groundnutbased snacks. *Journal of Food Processing and Preservation*, 5, 1–8.
- Igbua, F. Z., Adejo, S. O., Igoli, N. P., & Daagema, A. A. (2020). Antinutrients and Bioavailability of Nutrients in Maize, Cassava and Soybeans Composite Flour. *Asian Food Science Journal*, 16(2), 5–12. <https://doi.org/10.9734/AFSJ/2020/v16i230167>
- Indasah, I., & Muhith, A. (2020). *Local Microorganism From “ Tape ” (Fermented Cassava) In Composition and Its Effect on Physical , Chemical And Biological Quality in Environmental Local Microorganism From “ Tape ” (Fermented Cassava) In Composition and Its Effect on Physical , Chemic.* <https://doi.org/10.1088/17551315/519/1/012003>
- Inyang, U. E., Effiong, C. F., & Edima-nyah, A. P. (2018). Physical Properties , Nutritional Composition and Sensory Evaluation of Cookies Prepared from Rice , Unripe Banana and Sprouted Soybean Flour Blends. *International Journal of Food Science and Biotechnology*, 3(2), 70–76. <https://doi.org/10.11648/j.ijfsb.20180302.15>
- Ishiwu, C., Obiegbuna, J., & Igwe Ec. (2015). Effect of Process Variables on Some Physical Properties and Hydrogen Cyanide Content of Dried Cassava Slices (“ abacha ”). *Journal of Food Processing & Technology*, 6(8), 6–10.
- Ismaila, A. R., Alakali, J. S., & Atume, T. G. (2018). Effect of Local Processing Techniques on the Nutrients and Anti-Nutrients Content of Bitter Cassava (*Manihot Esculenta* Crantz). *American Journal of Food Science and Technology*, 6(3), 92–97.
- Jan, T., Hussain Syed Zameer, & Rafiq, A. (2022). “Shelf life studies of the optimized chiacorn based snacks developed by extrusion processing“. *The Pharma Innovation Journal*, 11(8), 1549–1552.
- John, H. (2017). *physiochemical properties and extrusion behaviour of selected common bean varieties.* <https://doi.org/10.1002/j>
- Jomaa, L. H., Mcdonnell, E., & Probart, C. (2017). School feeding programs in developing countries : impacts on children ’ s health and educational outcomes. *Nutrition Research*, 69(2), 83–98.
- Juwon, A. D., & Cyrus, E. T. (2015). *Comparative Effects of Yeasts Sourced from Different Environments on Organoleptic Qualities of Bread Produced from Air Potato-Cassava-Wheat Composite Flour.* 308(319). <https://doi.org/10.3923/jm.2015.308.319>
- Kadam ML, RV, S., ZM, M., & SG, M. (2012). Development and Evaluation of Composite Flour for Missi roti / chapatti. *Food Processing & Technology*, 3(1), 1–7.
- Kajura, R. B., Veldman, F. J., & Kassier, S. M. (2020). Maternal perceptions and barriers experienced during the management of moderately malnourished children in northern Uganda. *Maternal & Child Nutrition*, 16, 1–11. <https://doi.org/10.1111/mcn.13022>
- Kaur, S., & Aggarwal, P. (2017a). Development of maize-potato tortilla chips : A nutritious and low fat snack food. *Journal of Pharmacognosy and Phytochemistry*, 6(4), 153–161.
- Kaur, S., & Aggarwal, P. (2017b). Development of maize-potato tortilla chips : A nutritious and low fat snack food. *Pharmacology and Phytochemistry*, 6(4), 153–161.

- Keyata, E. O., Forsido, F., Tola, Y. B., & Bultosa, G. (2021). Premilling treatments effects on nutritional composition , antinutritional factors , and in vitro mineral bioavailability of the improved Assosa I sorghum variety (*Sorghum bicolor* L .). *Food Science & Nutrition*, 1–10. <https://doi.org/10.1002/fsn3.2155>
- Khor, G. L., & Misra, S. (2012). Micronutrient interventions on cognitive performance of children aged 5-15 years in developing countries. *Asia Pacific Clinical Journal*, 21(4), 476–486.
- Kolliesuah, N. P., Olum, S., & Ongeng, D. (2023). Status of household dietary diversity and associated factors among rural and urban households of Northern Uganda. *BMC Nutrition*, 9, 1–16. <https://doi.org/10.1186/s40795-023-00739-4>
- Konyo, B. O., Submitted, A. D., The, T. O., Of, D., For, R., Award, T. H. E., Degree, O. F., Of, M., In, S., & Human, A. (2019). *Enrichment of Flour of Indigenous Bitter Cassava “Lenga tome” for Feeding Infants and Young Children (6-23 months) in kajo-keji. february.*
- Kuliah Sari, D. E., Sari, I. N. I., & Estiasih, T. (2021). Cyanide detoxification methods in food: A review. *IOP Conference Series: Earth and Environmental Science*, 733(1). <https://doi.org/10.1088/1755-1315/733/1/012099>
- Kumar, Y., Sharanagat, V. S., Singh, L., Gundev, P., & Mani, S. (2020). Qualitative Analysis of Roasted and Germinated Green Chickpea for Snack Food: Proximate, Functional and Pasting Properties. *Journal of Agricultural Engineering (India)*, 57(3), 226–235.
- Kumari, R., Bharti, R. K., Singh, K., & Sinha, A. (2017). Prevalence of Iron Deficiency and Iron Deficiency Anaemia in Adolescent Girls in a Tertiary Care Hospital. *Journal of Clinical and Diagnostic Research*, 11(8), 10–12.
- Kwabla, M. P., Gyan, C., & Zotor, F. (2018). Nutritional status of in-school children and its associated factors in Denkyembour District , eastern region , Ghana : comparing schools with feeding and non-school feeding policies. *Nutrition Journal*, 17(8), 1–8.
- Kwofi, M. K. (2021). School Feeding and the Challenge of Supporting Nutritional Needs of Pupils in Ghana. *Food Science & Nutrition Research*, 4(1), 1–6.
- Lestienne, I., Pierre, B., Caporiccio, B., Llerin, V. rie lullien-peä, & Che, and serge treä. (2005). Iron and Zinc in Vitro Availability in Pearl Millet Flours (*Pennisetum glaucum*) with Varying Phytate , Tannin , and Fiber Contents. *Agriculture and Food Chemistry*, 53(8), 3240–3247.
- Leticia, S., Meza, R., Ramos, A. H., Gaiosio, A., Egea, I., Estrada, Y., Flores, F. B., & Oliveira, M. De. (2023). Review A review on amaranth protein : composition , digestibility , health benefits and food industry utilisation. *International Journal of Food Science and Technology*, 58, 1564–1574.
- Linda, P., Charlotte, R., & Serrem, A. (2020a). Effect of soy fortification on the quality of Mkarango a traditional Kenyan fermented maize meal snack. *Food Science and Nutrition*, 5007–5016. <https://doi.org/10.1002/fsn3.1798>
- Linda, P., Charlotte, R., & Serrem, A. (2020b). Effect of soy fortification on the quality of Mkarango a traditional Kenyan fermented maize meal snack. *Food Science and Nutrition*, 8, 5007–5016. <https://doi.org/10.1002/fsn3.1798>
- Lobanov, V. G., Slepokurova, Y. I., & Zharkova, I. M. (2018). *Economic effect of innovative flour-based functional foods production.* 6(2), 0–8.

- Ma, O., Jo, I., & Af, O. (2023). Physiochemical properties of composite maize-ogi almond flour blends. *Journal On Nutritional Health and Food Engineering*, 13(April), 15–18.
- Mahati, R. V., Lalitha, S., Hymavathi, T. V., Devi, K. U., & Robert, T. P. (2018). Nutrients , phytochemicals and antioxidant activity in whole and dehulled nutri-cereal based multigrain extruded snacks. *International Journal of Chemical Studies*, 6(6), 765–769.
- Makame, J., Cronje, T., Emmambux, N. M., & De Kock, H. (2019). Dynamic oral texture properties of selected indigenous complementary porridges used in African communities. *Foods*, 8(6).
- Makori, N., Kassim, N., Kinabo, J., & Matemu, A. (2018). Factors associated with stunting in Dodoma Region, Tanzania. *African Journal of Food, Agriculture, Nutrition and Development*, 18(3), 13842–13861. <https://doi.org/10.18697/AJFAND.83.17000>
- Abbas, Y., & Ahmad, A. (2021). Impact of processing on nutritional and antinutritional factors of legumes: A review. *Revista Mexicana de Ingeniera Quimica*, 20(3), 199–215.
- Adejumo PO, Adejumo AO, Edebiri OE, & Olukoya FO. (2020). Effect of unripe banana and pigeon pea flour on the chemical, anti-nutritional and sensory properties of whole wheat-based cookies. *GSC Advanced Research and Reviews*, 4(1), 017–023. <https://doi.org/10.30574/gscarr.2020.4.1.0050>
- Adoko, M. C., Olum, S., Elolu, S., & Ongeng, D. (2021). Addition of Orange Fleshed Sweet Potato and Iron Rich Beans Improves Addition of Orange-Fleshed Sweet Potato and Iron-Rich Beans Improves Sensory , Nutritional and Physical Properties But Reduces Microbial Shelf Life of Cassava-Based Pancake (Kabalagala. *Journal of Culinary Science & Technology*, 25(2), 1–25.
- Affrifah, N. S., Uebersax, M. A., & Amin, S. (2023). Nutritional significance, value-added applications, and consumer perceptions of food legumes: A review. *Legume Science*, 5(4), 1–16. <https://doi.org/10.1002/leg3.192>
- Afifah, D. N., Ma'ruf, A., Putri, R. N., Hamad, A., & Santosa, A. P. (2024). Production of High Protein MOCAF (Modified Cassava Flour) Using Papain and Lactic Acid Bacteria. *Molekul*, 19(1), 152–161.
- Alamu, B. M. E. O., Popoola, I. O., & Yomeni, M. (2017). Nutritional and sensory properties : Snack food made from quality cassava flour and legume blend. *Food Science & Nutrition*, 5(1), 805–811.
- Alcantara, M. A., & Fronterras, M. A. (2024). The Impact of Nutritional School Based Feeding Program on Academic Achievement of Selected Elementary Learners in West Philippines. *International Journal of Education and Teaching Zone.*, 3(1), 1–2.
- Amoadu, M., Abraham, S. A., Adams, A. K., Akoto-Buabeng, W., Obeng, P., & Hagan, J. E. (2024). Risk Factors of Malnutrition among In-School Children and Adolescents in Developing Countries: A Scoping Review. *Children*, 11(4), 1–19.
- Annanya Sardar, D. K. B. (2024). Wash Practices of School - Going Children in South Asia. *IRJEMS International Research Journal of Economics and Management Studies*, 3(1), 255–262.
- Anwar, H., Hussain, A., Samin, G., Kausar, T., & Rehman, A. (2024). Evaluation of Quality and Sensory Attributes of Potato Chips Fried in Different Oils and Their Blends , and Chemical Changes Occurred in Oils During Different Frying Counts. *Journal Technique*, 11(1), 42–53.
- Anwar, W., Nurjazuli, N., & Joko, T. (2024). The Relationshio Household Environmental Sanitation with Incidence of Stunting in Toddlers:Literature Review. *The Indonesian Journal of Health Promotion*, 7(10), 2422–2429.
- Bork, L. V., Proksch, N., Stobernack, T., Rohn, S., & Kanzler, C. (2024). Influence of Hydroxycinnamic Acids on the Maillard Reaction of Arabinose and Galactose beyond Carbonyl-Trapping. *Journal of Agricultural and Food Chemistry*, 72, 15933–15947.

- <https://doi.org/10.1021/acs.jafc.4c02959>
- Buser, M., Brännlund, E., Holt, N. J., Leeson, L., Buser, M., Brännlund, E., Holt, N. J., Leeson, L., Holt, N. J., & Leeson, L. (2024). Creating a difference – a role for the arts in addressing child wellbeing in conflict-affected areas. *Arts & Health*, 16(1), 32–47. <https://doi.org/10.1080/17533015.2023.2168710>
- Buzigi, E., Pillay, K., Siwela, M., Mkhwanazi, B., Ngidi, M., Ssozi, J., Muhindo, B., & Isingoma, E. B. (2024). *Lactating mothers' perceptions and sensory acceptability of a provitamin A carotenoid – iron- - rich composite dish prepared from iron- - biofortified common bean and orange- - fleshed sweet potato in rural western Uganda*. October 2023, 3949–3963. <https://doi.org/10.1002/fsn3.4053>
- Castro-Alba, V., Vargas, M., Sandberg, A. S., Perez-Rea, D., Bergenståhl, B., Granfeldt, Y., & Lazarte, C. E. (2024). Fermented Quinoa and Canihua in Plant-Based Diets Increase Iron and Zinc Bioavailability in Growing Rats. *Food Science and Nutrition*, 12, 9555–9565.
- Chad, J. A., & Lebel, C. (2024). Can gray matter loss in early adolescence be explained by white matter growth? *Human Brain Mapping*, 45(9), 1–14.
- Chaudhuri, N., Hussain, L., & Ashleigh, A. (2024). Long - term support referrals to enhance food security and well - being in older adults : Texas physicians and nurses on what works. *Journal of Public Health*, 32(3), 421–433. <https://doi.org/10.1007/s10389-022-01800-5>
- Ciemniecki, J. A., & Newman, D. K. (2023). NADH dehydrogenases are the predominant phenazine reductases in the electron transport chain of *Pseudomonas aeruginosa*. *Molecular Microbiology*, 119(5), 560–573.
- Cowan, D. A., Babenko, D., Bird, R., Botha, A., Breecker, D. O., Clarke, C. E., Francis, M. L., Gallagher, T., Lebre, P. H., Nel, T., Potts, A. J., Trindade, M., & Van Zyl, L. (2024). Oxalate and oxalotrophy: an environmental perspective. *Sustainable Microbiology*, 1(1).
- De Lacerda, A. T., Do Carmo, A. S., Maia De Sousa, T., & Dos Santos, L. C. (2023). NOVA food groups' consumption associated with nutrient intake profile of school children aged 8-12 years. *Public Health Nutrition*, 26(1), 56–62.
- Dewidar, O. M., & El, H. M. A. (2020). Development of extruded snacks and corn flakes using yellow corn and by-product broken beans. *Middle East Journal of Applied Sciences*, 10(2), 390–406.
- Dominguez-lópez, I., Pérez, M., & Lamuela-raventós, R. M. (2024). Total (poly) phenol analysis by the Folin-Ciocalteu assay as an anti-inflammatory biomarker in biological samples. *Critical Reviews in Food Science and Nutrition*, 64(27), 10048–10054. <https://doi.org/10.1080/10408398.2023.2220031>
- Ezekiel, O. ., Adedeji, O. ., & Umuokeke, N. (2022). 2* 1 1 2. *Agrosearch*, 21(1&2), 89–101.
- Fuadi, D. S. (2024). Building Public Awareness : Education and Campaigns to Prevent Stunting in the Next Generation. *International Conference on General Health Sciences*, 13(5), 88–97.
- Gómez-Gaete, C., Avendaño-Godoy, J., Escobar-Avello, D., Campos-Requena, V. H., Rogel-Castillo, C., Estevinho, L. M., Martorell, M., Sharifi-Rad, J., & Calina, D. (2024). Revolutionizing fruit juice: exploring encapsulation techniques for bioactive compounds and their impact on nutrition, flavour and shelf life. *Food Production, Processing and Nutrition*, 6(1). <https://doi.org/10.1186/s43014-023-00190-9>
- Herdeiro, F. M., Carvalho, M. O., Nunes, M. C., & Raymundo, A. (2024). Development of Healthy Snacks Incorporating Meal from *Tenebrio molitor* and *Alphitobius diaperinus* Using 3D Printing Technology. *Foods*, 13(2), 1–16.
- Iyer, K. V., & Siddhartha, A. (2024). Perceived obstacles to implementing healthy eating habits amongst pre-adolescent Indian children—a parental perspective. *International Journal of Adolescence and Youth*, 29(1). <https://doi.org/10.1080/02673843.2024.2398037>
- Jesulagba, T. J., Andrea, D., & ... (2024). Cost Evaluation of Bread Production from Composite of Wheat Flour and Corn Flour. *Asian Journal of ...*, 3(1), 190–201.

- <http://research.sdpublishers.net/id/eprint/4019/%0Ahttp://research.sdpublishers.net/id/eprint/4019/1/Andrea312024AJFRN113854.pdf>
- Johnson, B. R. (2024). Frontmatter (Volume 17, Issue 1). *Sehnsucht: The C. S. Lewis Journal*, 17(1). <https://doi.org/10.55221/1940-5537.1410>
- K, E. E., Ram, A., & Mishra, K. (2024). Development and Nutritional Assessment of Ginger Candy Supplemented with Beetroot Pomace Powder. *Asian Journal of Advanced Research and Reports*, 18(11), 235–243.
- Kiliobas, K. S. H., Clarkson, G. P., & Artimas, S. P. (2019). Phytochemical analysis , proximate composition and antinutritional factors of Corchorus oliterius plant. *International Journal of Biological and Chemical Sciences*, 13(4), 2147–2157.
- Kolliesuah, N. P., Olum, S., & Ongeng, D. (2023). Status of household dietary diversity and associated factors among rural and urban households of Northern Uganda. *BMC Nutrition*, 9(1), 1–16. <https://doi.org/10.1186/s40795-023-00739-4>
- Kumar, A. T. V., Mani, I., Pramod, A., Samuel, D. V. K., Jha, S. K., Sahoo, P. K., Sinha, J. P., & Kar, A. (2018). Effect of extrusion technique on antinutritional factors of sorghum-soya blends. *Indian Journal of Agricultural Sciences*, 88(3), 420–428.
- Lipa, R. C. (2024). Conditional cash transfer program, child malnutrition and school dropout in the high Andean region of Peru. *International Journal of Interdisciplinary Studies*, 5(4), 1–8.
- Lyabole, O. O., Aanuoluwapo, A. M., Alonge Sunday Ayodele, A. C. C., & Dorcas, A.-D. O. (2024). Comparative assessment of Nutraceutical Potential of Orange Flesh Sweet Potato and Sprouted white sorghum for the management of malnutrition and Micronutrient deficiency in Ekiti state , Southern. *American Journal of Pharmacy and Health Research*, 12(04), 1–9.
- Makhuvha, M. C., Laurie, S., & Mosala, M. (2024). Effect of orange-fleshed sweet potato (Ipomoea batatas)–Bambara groundnut (Vigna subterranea) composite flour on quality properties of pasta. *Journal of Food Science*, 89(9), 7348–7359.
- Maniragaba, V. N., Atuhair, L. K., & Rutayisire, P. C. (2023). Modeling the Risk Factors of Undernutrition among Children below Five Years of Age in Uganda Using Generalized Structural Equation Models. *Children*, 10(12), 1–14.
- Miyingo Charles, Tukahirwa Sylvia, Maniragaba John Mathew, A. S. (2024). Nutrition Education and Childhood Malnutrition : A Case Study of Arua District. *Metropolitan Journal Of Medical and Health Research*, 3(10), 198–209.
- Mmbone, A., Lawrence, U., & Duncan, O. (2023). Development of micronutrient dense composite flour for routine enrichment of complementary foods for children 6 – 24 months old in Acholi sub - region of Uganda. *Discover Food*, 3(24), 1–10.
- Mohanto, K., & Aye, A. T. (2024). An Analysis of Health Risk and Potential Elimination Strategies of Anti-nutritional Factors in Cereals and Legumes. *Asian Food Science Journal*, 23(7), 44–51.
- Mukuwapasi, B., Mavengahama, S., & Shegro, A. (2024). Grain amaranth : A versatile untapped climate - smart crop for enhancing food and nutritional security. *Discover Agriculture*, 2(44). <https://doi.org/10.1007/s44279-024-00057-8>
- Muñoz, E. C., Rosado, J. L., López, P., Furr, H. C., & Allen, L. H. (2000). Iron and zinc supplementation improves indicators of vitamin A status of Mexican preschoolers. *American Journal of Clinical Nutrition*, 71(3), 789–794. <https://doi.org/10.1093/ajcn/71.3.789>
- Murray, R. D., Shaaban, S. Y., Al Amrani, M., Aldekhail, W., Alhaffaf, F. A., Alharbi, A. O., Almehaidib, A., Al-Suyufi, Y., Al-Turaiki, M., Amin, A., Hasosah, M. Y., Alkhormi, M., Mirza, Z. T., Sleiman, R., & Sukkar, G. (2024). Protecting optimal childhood growth: systematic nutritional screening, assessment, and intervention for children at risk of malnutrition in the Kingdom of Saudi Arabia. *Frontiers in Nutrition*, 11(2). <https://doi.org/10.3389/fnut.2024.1483234>

- Nabuuma, D., Ekesa, B., Faber, M., & Mbhenyane, X. (2024). Designing a Contextualized Food-Based Strategy to Improve the Dietary Diversity of Children in Rural Farming Households in Central Uganda. *Food and Nutrition Bulletin*, 45(1), 24–37.
- Naicker, A., & Singh, E. (2020). Snack Development for School Feeding Programs in Africa : A Scoping Review. *International Journal of Environmental Research and Public Health*, 17, 1–13.
- Naisiae, G. S., & Mungai, A. M. W. (2024). Monitoring and Evaluation systems and performance of Integrated Management of Acute Malnutrition Projects In Narok County, Kenya. *International Journal of Sciences Management and Entrepreneurship*, 8(1), 385–399.
- Nande, P. J. (2024). Sensory And Nutritional Quality Of Nutri Bars Prepared Using Different Ingredients, Educational Administration: Theory and Practice. *Citation: Prajakta J. Nande*, 2024(5), 12539–12549. <https://kuey.net/>
- Natabirwa, H., Nakimbugwe, D., Lung'aho, M., Tumwesigye, K. S., & Muyonga, J. H. (2020). Bean-based nutrient-enriched puffed snacks: Formulation design, functional evaluation, and optimization. *Food Science and Nutrition*, 8(9), 4763–4772.
- Netshishivhe, M., Omolola, A. O., Beswa, D., & Mashau, M. E. (2019). Physical properties and consumer acceptance of maize-baobab snacks. *Heliyon*, 5(3), 1–17. <https://doi.org/10.1016/j.heliyon.2019.e01381>
- Nfula, D. O., Alowo, L., Nabatanzi, & Zziwa. (2022). Effect of Cereal Based Traditional Malting Technology on Nutritional Quality of Iron-Rich Bean Flour. *African Crop Science Journal*, 30(1), 85–107.
- Ngungulu, T. P., Wenaty, A., Chove, B., Suleiman, R., & Mbwana, H. (2024). Effect of Different Processing Methods on the Anti-nutritive Components of Selected Indigenous Vegetables. *Asian Food Science Journal*, 23(8), 80–94. <https://doi.org/10.9734/afsj/2024/v23i8737>
- Nkanga, A. U., & Inyang, U. E. (2024). Quality Evaluation of Flour and Crackers Made from Acha and Orange-Fleshed Sweet Potato Composite Flour Supplemented with Fermented Cowpea Flour. *African Journal of Agricultural Science and Food Research*, 16(1), 01–19.
- Nodoushan, A. J., Sayedi, S. J., & Najarzadeh, A. (2021). Dietary Intake of Macro- and Micronutrients in children : Comparison with Reference Values. *International Journal of Pediatrics*, 9(10), 14672–14679.
- Nour, A. A. M. (2024). Supplementation and Fermentation of Sorghum Flour : Changes in Ash , Protein and Minerals contents . *Egyptian Journal of Nutrition*, 39(3), 146–153.
- Odiaka, P., Eke, O., & M, T. E. (2024). Functional and Physicochemical Properties of Flour and Cookies from Wheat Soybean and Orange Fleshed Potatoes Blend. *Asian Food Science Journal Volume*, 23(7), 22–35.
- Oduro-Obeng, H., & Plahar, W. A. (2017). African Journal of Food Science Development, quality evaluation and estimated contribution of composite flour snack foods to nutrient requirements of young children aged 2 to 6 years. *African Journal of FOOD Science*, 11(9), 318–329. <http://www.academicjournals.org/AJFS>
- Olaniyi, M. B., Olaniyi, A. A., Rufai, S. O., & Ogunbamowo, P. O. (2024). Impacts of non-nutritive compounds on the bio- accessibility of critical mineral elements in red vine fruits. *Agriculture, Food and Nutrition Resources Journal*, 3(2), 190–197.
- Omojokun, A. O., Ojokoh, A. O., & Akinyosoye, F. A. (2021). *Nutritional composition of fermented and extruded blends of cassava and African yam beans flour*. 2, 53–63. <https://doi.org/10.30493/DAS.2021.290155>
- Palupi, E., Nurdin, N. M., Mufida, G., Valentine, F. N., Pangestika, R., Rimbawan, R., Sulaeman, A., Briawan, D., & Filianty, F. (2024). High-Fiber Extruded Purple Sweet Potato (*Ipomoea batatas*) and Kidney Bean (*Phaseolus vulgaris*) Extends the Feeling of Fullness. *Polish Journal of Food and Nutrition Sciences*, 74(1), 82–91. <https://doi.org/10.31883/pjfn/183995>

- Patiballa, M., Ravindra, U., Benherlal P. S., Subbarayappa, C. T., Shivakumar, N., Mamatha H. S., & Vijayalaxmi, K. G. (2024). Effect of Soaking and Germination on Antinutritional Factors of Quinoa (*Chenopodium quinoa*). *International Journal of Plant & Soil Science*, 36(1), 120–130. <https://doi.org/10.9734/ijpss/2024/v36i14337>
- Patil, R., Singh, A., Mane, S., & Roy, T. (2024). Emerging encapsulation strategies for vitamin A fortification in food sector: an overview. *Food Science and Biotechnology*, 33(13), 2937–2951. <https://doi.org/10.1007/s10068-024-01635-8>
- Rahimi, B. A., Khalid, A. A., Lali, W. M., Khalid, W. A., Rahimi, J. A., & Taylor, W. R. (2024). Prevalence and associated risk factors of stunting, wasting/thinness, and underweight among primary school children in Kandahar City, Afghanistan: a cross-sectional analytical study. *BMC Public Health*, 24(1). <https://doi.org/10.1186/s12889-024-19858-z>
- Ramos, K. A., Nunez, Á. B., Halimi, C., Maillot, M., Vernière, C. I., Forti, C., Preite, C., Ferrari, L., Sala, T., Losa, A., Cominelli, E., Sparvoli, F., Camilli, E., Lisciani, S., Marconi, S., Georgé, S., Rivier, C. M., Kunert, K., & Reboul, E. (2024). Improving the antinutritional profiles of common beans (*Phaseolus vulgaris* L .) moderately impacts carotenoid bioaccessibility but not mineral solubility. *Scientific Reports*, 1–12. <https://doi.org/10.1038/s41598-024-61475-8>
- Reggi, D., Alessio, G., Ndereyimana, A., Minuti, A., Spigno, G., & Bertoni, G. (2024). Ready-to-Use Supplementary-Food Biscuit Production with Low-Cost Ingredients for Malnourished Children in Sub-Saharan Africa. *Foods*, 13(11).
- Rigo, G. A., Schuch, L. O. B., Vargas, R. L. de, Barros, W. S., Szareski, V. J., Carvalho, I. R., Troyjack, C., Pimentel, J. R., Escalera, R. A. V., Rosa, T. C. da, Souza, V. Q. de, Aumonde, T. Z., & Pedó, T. (2018). Micronutrient Content and Physiological Quality of Soybean Seeds. *Journal of Agricultural Science*, 10(4), 223.
- Sanya Emmaculate, Wandayi, O. M., Ooko, A. G., & Kadenyeka, M. V. (2020). Nutrient and Anti-Nutrient Composition of Extruded Cereal Flours Fortified with Grain Amaranth, Baobab and Orange-fleshed Sweet Potato Powder. *Journal of Food Research*, 9(6), 21.
- Sarmin, S., Hasan, F., Sayed, A., Rahman, Z., & Karim, R. (2024). Food security status and its determinants : A comparative study between farm households under government and non-government agricultural extension services in Bangladesh. *Journal of Agriculture and Rural Development in the Tropics and Subtropics*, 125(1), 43–55.
- Schutte, M., Hayward, S., & Manley, M. (2024). Nonenzymatic Browning and Antioxidant Properties of Thermally Treated Cereal Grains and End Products. *Journal of Food Biochemistry*, 2024. <https://doi.org/10.1155/2024/3865849>
- Sciarini, L. S., Ribotta, P. D., León, A. E., & Pérez, G. T. (2010). Influence of Gluten-free Flours and their mixtures on batter properties and bread quality. *Food and Bioprocess Technology*, 3(4), 577–585.
- Sheffield, S., Fiorotto, M. L., & Davis, T. A. (2024). Nutritional importance of animal-sourced foods in a healthy diet. *Frontiers in Nutrition*, 11(July), 1–6.
- Sobarasua, O. G., Onuche, I. F., Kuye, A. O., Diemuodeke, E. O., Muritala, I. K., Saturday, E. G., Okedu, K. E., & Kalam, A. (2024). Sustainable innovation for fermented cassava roasting: Examining the potential of parabolic dish solar collectors and thermal energy storage. *Heliyon*, 10(20), e39627. <https://doi.org/10.1016/j.heliyon.2024.e39627>
- Sowa, M., Yu, J., Palacios-Rojas, N., Goltz, S. R., Howe, J. A., Davis, C. R., Rocheford, T., & Tanumihardjo, S. A. (2017). Retention of Carotenoids in Biofortified Maize Flour and β -Cryptoxanthin-Enhanced Eggs after Household Cooking. *ACS Omega*, 2(10), 7320–7328. <https://doi.org/10.1021/acsomega.7b01202>
- Susanto, N. G., & Hartati, F. K. (2024). Different Concentrations Of Cassava Flour (*Manihot utilisima*) And Wheat Flour On The Physicochemistry And Organoleptic Quality Of High-Fiber Steamed Brownies. *Journal of Farming and Agriculture*, 2(1), 85–93.
- Syan, V., Kaur, J., Sharma, K., Patni, M., Rasane, P., Singh, J., & Bhadariya, V. (2024). An

- overview on the types, applications and health implications of fat replacers. *Journal of Food Science and Technology*, 61(1), 27–38.
- Terefe, Z. K., Omwamba, M., & Nduko, J. M. (2022). Effect of microbial fermentation on nutritional and antinutritional contents of cassava leaf. *Journal of Food Safety*, 42(3), 1–12.
- Tesfaye, T. S., Szymlek-Gay, E. A., Campbell, K. J., & Zheng, M. (2024). Dietary fat intakes and food sources in early childhood: results from the Melbourne Infant Feeding, Activity and Nutrition Trial (InFANT) Program. *Proceedings of the Nutrition Society*, 83(1), 3547.
- Udo, U., Udo, A., & Dan, E. (2018). Determination of Nutrient, Antinutrient Compositions and Median Lethal Dose of Leaves of *Microdesmis puberula* Grown in Nigeria. *Journal of Scientific Research and Reports*, 17(4), 1–10.
- Vaiciurgis, V. T., Clancy, A. K., Charlton, K. E., Stefoska-Needham, A., & Beck, E. J. (2024). Supporting the nutrition-related health and well-being of people experiencing socio-economic disadvantage: Findings from a national survey. *Journal of Human Nutrition and Dietetics*, 37(2), 1349–1360.
- Wang, X., Wang, Q., Wang, X., & Wang, Q. (2024). Current Dietary and Medical Prevention of Renal Calcium Oxalate Stones Current Dietary and Medical Prevention of Renal Calcium Oxalate Stones. *International Journal of General Medicine*, 17, 1635–1649. <https://doi.org/10.2147/IJGM.S459155>
- Zulfiqar, U., Ayub, A., Hussain, S., Ahmad, M., Rehman, A., Ishfaq, M., Ali, M. F., Shabaan, M., & Yong, J. W. H. (2024). Iron biofortification in cereal crops: Recent progress and prospects. *Food and Energy Security*, 13(4), 1–28. <https://doi.org/10.1002/fes3.547>

APPENDIX 1: PLAGIARISM CHECK REPORT

GULU

P.O. Box 166
Gulu, Uganda



UNIVERSITY

Tel: +256-471-32924
Fax: +256 471343095
Emails: ul@gu.ac.ug
URL: www.gu.ac.ug

OFFICE OF THE UNIVERSITY LIBRARIAN

PLAGIARISM CHECK

Declaration for Originality Form

This form must be completed and signed for all scholarly work produced.

Name: MR. ULANGO TOM

Personal File No.(staff) Reg. (student). 18/U/3035/MFN

Faculty/Institute: AGRICULTURE AND ENVIRONMENT, GULU UNIVERSITY

Department: FOOD SCIENCE AND POSTHARVEST HANDLING

Title and bibliographic description of the work:

DEVELOPMENT OF NUTRIENT ENRICHED CASSAVA AND ORANGE FLESHED SWEET POTATO-BASED SNACK FOR SCHOOL FEEDING OF CHILDREN AGED 6-15 YEARS

Declaration.

1. I understand what plagiarism is and I am aware of the University policy on this regard,
2. I declare that this ...**Dissertation**... (thesis, dissertation, essay, assignment, paper, report etc.) is my original work and has not been submitted elsewhere for examination, award of a degree or publication. Where other people's work or my work has been used, this has been properly acknowledged and referenced in accordance with Gulu University requirements,
3. I have not sought or used the services of any professional agency to produce this work,
4. I have not allowed, and shall not allow anyone to c.c copy my work with the intention of passing it off as his/her own,
5. I understand that any false claim of this work shall result in disciplinary action in accordance with University Policy on Plagiarism.

Signature

Date

24/1/2023

Originality Report

The article/thesis/document titled above have been subjected to plagiarism check and the level was found to be.....**19%** (percent) this is classified as:

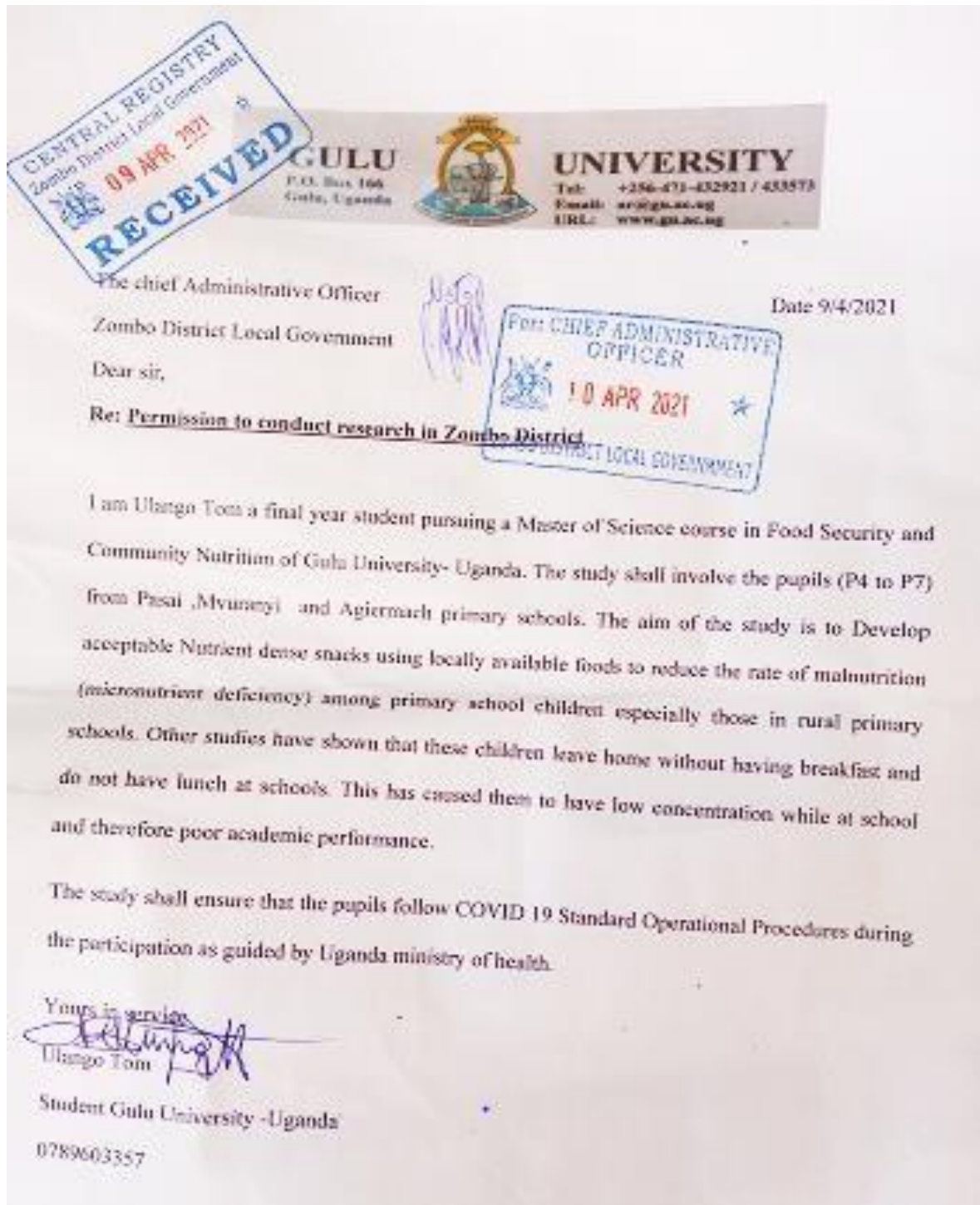
- ☒ Minor
☐ Moderate
☐ Serious

Yours sincerely,

Mariama N Herbert
Ag. University Librarian



APPENDIX 2: LETTER OF PERMISSION FROM CAO ZOMBO DISTRICT



APPENDIX 3: CONSUMER PREFERENCE AND ACCEPTABILITY DATA ENTRY FORM

Consumer preference and acceptability evaluation tool for the developed snack products

Snack product flour blends: Cassava, Orange Fleshed Sweet Potatoes, Amaranth seeds, Iron Rich Beans Flour, and Iron Rich Beans Flour

Sample snacks	Attributes/Ranks (1-Dislike most, 2- like,3- Neither like nor Dislike,4-Like 5- Like most)				
	Colour	Taste	Flavour	Mouth feel	Overall acceptability
A					
B					
C					
N					
P					
D					
G					
H					
E					
O					
I					
F					
T					
V					
J					
Q					
R					
K					
M					
S					
L					
U					
Y					
X					

Control snacks (C, D, E, F, J, K, L, X) **SP2**

SP1 (A/B) SP2(N/P), SP3(G/H), SP4(O/I), SP5(T/V), SP6(Q/R), SP7(M/S), SP8(U/Y)

APPENDIX 4: DATA COLLECTION SHEET ON SNACKS

This data collection sheet is for the collection of laboratory data on developed snacks to determine the level of macro, micronutrients and antinutritional factors.

[illegible]

APPENDIX 5. INFORMED CONSENT FORM FOR INDIVIDUAL INTERVIEW

Title of the study: Development of nutrient-enriched cassava and orange-fleshed sweet potato-based snack for school feeding of children

Investigator(s) Ulango Tom

Institution(s) Gulu University

Introduction

Good day, afternoon, or evening? My name is Ulango Tom, and I am a student at Gulu University doing a Master of Science in Food Security and Community Nutrition. The study focuses on developing a nutrient-rich snack of orange-fleshed sweet potatoes and cassava. The study seeks to develop nutrient-dense snacks that might lower malnutrition among children in the Zombo District who are 6 to 15 years old. You took part in creating the snacks, from the initial ingredients to the finished snacks, and all of the questions you raised during the assessments were satisfactorily addressed. The consent documents must be signed, and you must maintain a copy of them.

Project sponsorship briefs

The project under-investigated has been self-sponsored by the investigator

Purpose of the study

The study seeks to develop nutrient-dense snacks for feeding children in primary schools, as some children in rural areas of Zombo are malnourished due to inadequate intakes of dietary foods. The study developed snacks using locally available but nutrient-rich foods; therefore, farmers' knowledge on the development of snacks shall increase as well as household incomes and food security situation in the region.

Procedure

Suppose any participant does not understand the question. In that case, the investigator will try to ensure that farmers know the procedure by reading the questionnaire and having the participants react correctly.

Who will participate in the studies

You were chosen to take part in this study because you are a student from one of the three primary schools—Pasai, Mvuranyi, or Agiermach—and you are between the ages of 8 and 15 years old, can read and write, and are in good health. At least 1 hour and 45 minutes must pass during the interview.

Risk/Discomfort

The investigation has no risks whatsoever, but the study may take longer, which may not be comfortable for some of the pupils who could be hungry.

Study benefits

We guarantee that the study participants will be updated on the findings and the study's progress and will be given access to any new information (even unintended findings) that impacts them. To better suit the needs of pupils in primary schools aged 6 to 15 years, improvements will be made to the formulas of the items' numerous snack options.

The participant's time shall be compensated in terms of refreshments and some off pocket of 3,000 Ugx at the end of each activity.

Confidentiality

Your identity will not be made public because we will only use codes to identify the participants. The information will only be accessible to the research team, and the researcher will keep a soft copy of the data in their email while keeping the hard copies locked away. Only the lead investigator will have access to sensitive data.

Alternatives

Only participants interested in the study shall be involved without any force.

Costs

The study will not require any additional due to children's participation in this study.

Questions

If you have any questions concerning the study or regarding your rights as a participant, you can contact Ulango Tom, the principal investigator, by telephone number 0789603357; you may come to the production office at Alangi Sub-County during office hours.

Statement of voluntariness

Participants are free to participate in this study at their discretion and to leave at any time without incurring any costs. If you have any issues about your rights and participation in the studies, please contact the chairperson, Gulu University Research Ethical Committee, Dr. Gerald Obai, Tel.No.,0772305621; email: lekobai@yahoo.com/lekobai@gmail.com; or the Uganda National Council for Science and Technology, on plot 6 Kimera Road, Ntinda, Kampala on Tel 0414705500.

Statement of consent

.....has explained to me the procedures that will be used, the risks, the advantages, and my rights as a participant in this study. I know my choice to participate in the study will not impact me. My identity will remain hidden while this data is used. I am conscious of my right to withdraw at any time. I know that signing this form signifies that I have been told about the research study in which I have willingly consented to participate as the actual participant. I do not, however, surrender any of my legal rights in doing so. I will receive a copy of this form.

Name Signature of participant Date

Name Signature of Head Teacher Date.....

Name Signature of witness Date.....

Name Signature of interviewer..... Date.....

APPENDIX 6: PHOTOGRAPH OF PLANT RAW MATERIALS AND FLOURS

Appendix 3. Snack materials



OFSP (NASPOT 12 variety)
maize



Amaranth seed flour



Yellow



NARO Bean2 Variety
local variety)



White maize



Cassava (*Nyarudota*)



Pupils are preparing OFSP Flour.



Ulango Tom formulating the composite flours using a digital weighing scale



Pupils making the dough

Photograph of snacks



Control snack SP2





Snacks prepared using the composite flours