Fortification of rapoko (*Eleusine coracana L*) and cowpeas (*Vigna unguiculata*) for improved macro and micro nutritents among children below the age of 5 years

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

(Production)

Bindura University of Science Education

Faculty of Agriculture and Environmental Science

Department of Agricultural Economics, Education and Extension

JOHN CHINYAMA

B1851511

SUPERVISOR DR.B. MASAMHA

July 2020

RELEASE FORM

Name of Candidate: John Chinyama

Reg Number: B1851511

Degree: Master of Science Degree in Food Security and Sustainable Agriculture

Project Title: FORTIFICATION OF RAPOKO *(Eleusine coracana L)* AND COWPEAS (Vigna *unguiculata)* FOR IMPROVED MACRO AND MICRO NUTRITENTS INTAKE AMONG CHILDREN UNDER THE AGE OF 5 YEARS.

Permission is hereby granted to **Bindura University of Science Education Library** to produce a single copy of this dissertation and lend such copy for private, scholarly, or scientific research only.

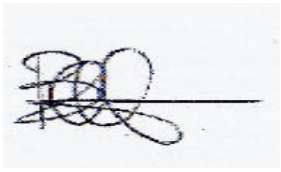
Signed: J. Chinyama

Permanent Address: House Number 24716, Runyararo North West, Masvingo

APPROVAL FORM

The undersigned certified that they have supervised and recommended to Bindura University of Science Education for acceptance of dissertation entitled "FORTIFICATION OF RAPOKO *(Eleusine coracana L)* AND COWPEAS *(Vigna unguiculata)*
FOR IMPROVED MACRO AND MICRO NUTRITENTS INTAKE AMONG CHILDREN UNDER THE AGE OF 5 YEARS'' submitted in partial fulfillment of a Master of Science Degree in Food Security and Sustainable Agriculture.

Name of supervisor: DR. B. Masamha

Signature: 

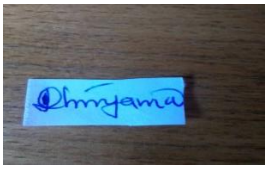
Date: **30 July 2020**

DECLARATION

I hereby declare that the research project entitled "FORTIFICATION OF RAPOKO (*Eleusine coracana L*) AND COWPEAS (*Vigna unguiculata*) FOR IMPROVED MACRO AND MICRO NUTRITENTS INTAKE AMONG CHILDREN UNDER THE AGE OF 5 YEARS" submitted to Bindura University of Science Education, Department of Agricultural Economics, Education and Extension is a record of an original work done by me under the guidance and supervision of **Dr . B. Masamha** and this work is submitted in partial fulfilment of the requirements for the award of a Master of Science Degree in Food Security and Sustainable Agriculture. The results embodied in this thesis have not been submitted to any University or Institute for the award of any degree of diploma.

Author: John Chinyama

Reg Number: B1851511

Signature: 

Date: 31 July2020

DEDICATION

This thesis is dedicated to my wife (Carr Chinyama) my kids; Tafadzwa, Tinodaishe and Tawananyasha for the patience they showed, and the support rendered during the time I was doing my research.

ACKNOWLEDGEMENTS

Many thanks and appreciation go to institutions and individuals whom without their help and support, the successful completion of my study would not have been possible. I would like to sincerely thank Dr Masamha who was my supervisor during the write up of this thesis. He provided me with the much-needed guidance and timely feedback during this study. I owe him so much for the knowledge gained and for his tireless effort in shaping this work. Many thanks go to Mr. Gombiro from the University of Zimbabwe for his assistance and guidance in the laboratory analysis of the Rapoko and Cowpea blend.

I extend my thanks to all lecturers and students at Bindura University of Science Education (BUSE) in the Department of Agricultural Economics, Education and Extension, and all those individuals who supported and reviewed my proposal as I pursued my studies. I would like to acknowledge the patience exercised by my wife over the prolonged periods I was away while working on this thesis. Finally, I thank God for his wonderful mercies to enable me to complete my study successfully.

ABSTRACT

This study aimed at developing a fortified Rapoko-Cowpea porridge blend named (RaCoB) and evaluate its acceptability to enhance macro and micronutrients intake among children below the age of 5 years. Rapoko proximate and mineral composition results were used as a control during blend formulation. Results of this research were compared to other studies and their ability to meet WHO daily nutrients requirements for children under the age of 5 years as a control mechanism. A Completely Randomised Design (CRD) was used with three treatments (blends) replicated three times. A mixed method research approach was adopted which consisted of an experiment (quantitative) for proximate analysis of rapoko, cowpeas and RaCoB ingredients. Sensory evaluation was done with 100 panelists to establish the overall acceptability of the blends. Vendors at Mbare market were categorized into three clusters based on where they source rapoko and cowpea grains (Masvingo, Murewa, Gokwe) as a way of managing uncontrolled variation. Simple random sampling was used to select three vendors where equal amounts of rapoko, and cowpea grains were bought and constituted to make 5 kg. Proximate analysis was done using standard AOAC methods for cow pea, rapoko and all the three formulated blends (RaCoB1; RaCoB2 and RaCoB3). The results of the proximate analysis showed that the mean difference in rapoko and cowpea elements is significant at 5% level. There is statistical significance difference in the proximate composition of the RaCoB blends at $p<0.05$. Blend ratio rapoko: cowpeas (75:25) had the highest carbohydrates, protein, zinc, iron, energy, and vitamins with blend (85:15) having the lowest. Sensory evaluation results from the three blends showed that blend ratio (75:25) was the most preferred blend. Women who normally feed porridge to children and have better olfactory blub necessary in determining sensory attributes than men also preferred the same blend. In conclusion the results have proved that rapoko, cowpeas and RaCoB blends have high macro and micronutrients to support daily nutritional requirements of children below the age of 5 years. Further studies are required to establish the effects of anti-nutritional factors, bioavailability, shelf life and commercialization of RaCoB blend. The government is therefore encouraged to invest more in nutrition and address inequalities in food, health systems. It may deliberately develop a policy that promotes fortification of cereals and pulses. Strengthening of the rapoko and cowpea value chain is required in terms at both input and output level.

Key words: Malnutrition, Fortification**,** Macro nutrients, Micronutrients, Cowpeas, Rapoko, Sensory evaluation,

LIST OF ACRONYMS AND ABBREVIATIONS

RacoB	Rapoko Cowpea Blend
FAO	Food and Agriculture Organisation
ZimVAC	Zimbabwe Vulnerability Assessment Committee
UNICEF	United Nations Children's Fund
UZ	University of Zimbabwe
UNDP	United Nations Development program
AOAC	Association of Analytical Chemistry
WHO	World Health Organization
LFSP	Livelihoods Food Security Project
ENSURE	Enhancing Nutrition Stepping Up Resilience and Enterprising
CRD	Complete Random Design

Table of Contents

RELEASE FORM ii
APPROVAL FORM iii
DECLARATION iv
CHAPTER 1 1
INTRODUCTION 1
1.1 Background of the study 1
1.2 Problem statement 3
1.3 Objectives 5
1.3.1 Main objective 5
1.3.2 Specific objectives 5
1.4 Hypothesis 5
1.5 Justification 5
1.6 Delimitations of the study 6
1.6.1 Limitations of the study 7
1.7 Outline of Thesis 7
CHAPTER 2 11
LITERATURE REVIEW 11
2.1 Introduction 11
2.3 Theoretical framework/s 22
2.4 Summary of literature Review 23
CHAPTER 3 27
METHODOLOGY 27
3.1 Introduction 27
3.2 Description of study site 27
3.3 Research design 28
3.4 Sampling procedure 30
3.5 Data collection procedure 31
3.7 Ethical considerations 40
3.8 Summary 40
3.9 References 41
CHAPTER 4 42
Proximate composition of Ingredients: Rapoko and Cowpeas and Rapoko-Cow pea (RaCoB) blends. 42
4.2 Material and Methods: Refer to Chapter 3 43

4.4 Discussion 48
4.5 Recommendations 51
4.6 Conclusion 52
4.7 References 53
CHAPTER 5: RESULTS Sensory acceptability evaluation of Rapoko-Cow pea (RacoB) developed porridge blend 54
5.1 Introduction 54
5.2 Material and Methods: 54
5.2 Results 55
5.4 Discussion 56
5.5 Recommendations 58
5.6 Conclusion 58
5.7 Reference 59
CHAPTER 6: SUMMARY, CONCLUSIONS AND RECOMMENDATIONS 60
6.1 Introduction 60
6.2 Research summary 60
6.3 Conclusions 60
6.4 Policy implication and recommendations 61
6.5 Areas for further research 61
6.6 References 62
Appendices 64

LIST OF TABLES

Table 2.1: Food elements and their functions..... 14
Table 2.2: Recommended elements for under 5 years according to WHO guidelines 16
Table 2.3: Summary of available Cowpea products 18
Table 2.4: Proximate and Fibre composition of Cowpea whole grain (% dry matter) 19
Table 2.5: Levels of mineral in Cowpeas whole grain in mg/g dry matter 20
Table 2.6: Levels of mineral in Cowpeas whole grain in mg/g dry matter 20
Table 3.1: RaCoB blends used in this study 28
Table 3.2: Data Analysis Methods 38
Table 4.1: Macro and Micronutrient content of Rapoko and Cowpeas / Dry matter basis 45
Table 4.3: Proximate and mineral content of rapoko, cowpeas and RaCoB 51
Table 5.1: Sensory evaluation result 55

LIST OF FIGURES

Figure 3.1: University of Zimbabwe Laboratory 27
Figure 3.2: Cowpea Flow Diagram 30
Figure 3.3: Rapoko Flow Diagram 31
Figure 3.4: Product Development Methods 39
Figure 5.1: Sensory evaluation blend ratio by gender 56

LIST OF APPENDICES

Appendix A Sensory Evaluation Questionnaire

Appendix B Rapoko and Cowpeas photos

CHAPTER 1
INTRODUCTION

1.1 Background of the study

About 13% of children globally are underweight, 6% suffer from acute malnutrition and 27% suffer from chronic malnutrition (Afshin, et al, 2020). Almost one billion people globally are undernourished and suffer from undernutrition, limited food diversity and lack of value addition and children under 5 years are impacted most (United Nations Children's Fund (UNICEF), 2019). Most countries globally have significant malnutrition burdens among children under the age of 5 years with 5-9% being overweight,21,9% being stunted and 7.3% wasted (Pelto G.H, 2003). United Nations Children's Fund (UNICEF) (2019), reported that 200 million children under the age of 5 years suffered from stunting or wasting and 340 million suffered from hidden hunger. In Zimbabwe malnutrition in children under 5 years is reported to be at 26% which is still very high as compared to global acceptable levels thereby proving that malnutrition is still a public health concern (UNICEF, 2019).

Malnutrition is one of the most important health and welfare problems for infants and young children in Zimbabwe due to inadequate food intake or illness with only 4% of the children receiving minimum acceptable diets (Afshin, et al,2020). Zimbabwe has 8% and 65% of the children under 5 years being able to consume iron and vitamin rich foods respectively due to food insecurity among other challenges (Zimbabwe Vulnerability Assessment Committee (ZimVAC), 2019). The emergence of Corona Virus (COVID-19) pandemic has exacerbated malnutrition crisis particularly among children under 5 years due to limited food access and availability. The COVID-19 pandemic has therefore exposed the fragility of food systems in low income countries such as Zimbabwe. Locally produced food initiatives may provide a lasting solution to this nutrition vicious cycle through local fortification cereals with pulses.

This new global challenge is straining food and nutrition systems and over stretching government social services like school feeding programs (Afshin, et al, 2020). Malnutrition is an umbrella term that exist when children have limited access to nutritious foods leading to under and over nutrition (Afshin, et al, 2020). It exists as acute, chronic, and moderate malnutrition. Stunting, wasting and underweight are the most challenges being experienced by children under 5 years of age. Lack of nutrients or too much of them may cause poor health and undermines a child's ability to lead a healthy life.

Malnutrition exists when a child is not able to obtain the right variety of nutrients in the right amounts from diet like macro nutrients which are required in large quantities (carbohydrates, Proteins) and micronutrients like Iron, Zinc required in small amounts. Under nutrition is common in developing countries and happens when there are deficiencies of a component of food due to insufficient intake or absorption of that component and in most cases refers to deficiencies in energy foods, macro nutrients (proteins) and micronutrients like Iron, Vitamins and Zinc in children under 5 years (World Food Programme, (WFP), 2006). Overnutrition is most prevalent in developed countries because of excess intake of energy foods or macro or micronutrient and usually results in overweight or obese. COVID 19 has increased inequalities in food and health systems thereby exacerbating malnutrition challenge that exists in the form of under and over overnutrition in children below the age of 5 years (Afshin, et al, 2020).

Macro and micro malnutrition is caused by lack of proteins, Iron, Zinc, Vitamin A, and calories and is affecting children most in developing countries. Food and nutrition security play an important role in improving health status of world's population especially that of children below the age of 5 years. Good nutrition is required during the first 2-3 years of a child's life for physical and mental development. Nutrition and good feeding are amongst the most important determinants of growth, health, and development as this prevent malnutrition and reduces the risk of infections, maximize psychomotor and cognitive development for children under 5 years (Garrow, 1999). It has been noted that malnutrition in under 5 years is posing a major threat to child development in developing countries due to micronutrient deficiency arising from poor diets (Talsma et al, 2017).

Only 41 Countries in the world are on course to meet the global nutrition target for under 5 years and 40 countries for wasting for the same age group thereby leaving a huge malnutrition gap to be addressed (Afshin, et al, 2020). A study by Food and Agricultural Organisation (2011), of the United Nations has indicated that world cowpea production is approximately 5.0 million tons from an estimated area of 10.5 million hectares and this will help support Rapoko-Cowpea fortification in this study. Over 60% of Zimbabwe's farmland lies in marginal regions best suited for production of Cowpeas and Rapoko. Insufficient food at household level and improper feeding practices (improper quality, quantity) have significant health and economic consequences that may lead to increased risk of deaths in children under the age of 5 years (Afshin, et al, 2020). The Afshin, et al, (2020) has also indicated that most deaths that occur before the age of 5 years are related to malnutrition that is; 22% due to mild to moderate and 2% due to severe malnutrition.

To alleviate this malnutrition crisis in children below the age of 5 years, smallholder farming communities need to fortify locally available cereals with pulses to enhance vitamin, iron, and zinc intake among children. This food fortification initiative may improve nutrition primarily because rapoko and cowpeas are important food crops that constitute most of the daily food sustenance for rural communities during drought years because of their adaptive advantage and low risk of failure in semi-arid regions (Mukarumbwa P, and Mushunje B, 2010).

Rapoko is primary source of energy in semi-arid tropics and drought prone regions of Asia and Africa. It is a good source of proteins, essential amino acids, minerals, and vitamins. (Ravindhran, R, 2017). It is important to note that there are international and national efforts being done towards fortification of staple foods, nutritional supplementation, and modification of traditional diets to meet specific nutritional requirements, but these are not sufficient enough in ending hunger and malnutrition in children (Awuchi, 2019). Available studies indicate that value addition can be done in three ways that is; primary, secondary, and high-end processing. This study fortified rapoko (*Eleusine coracana L*) with cowpeas (*Vigna unguiculata)* to produce a product that may support nutrition of children under the age of 5 years. Fortification of these two grains may help increase the nutritional value and consumer appeal of Rapoko-Cowpea Blend (RaCoB). This may increase availability of low-cost nutritious foods for undernourished children.

1.2 Problem statement

Malnutrition is the major underlying cause of child morbidity and mortality (UNICEF, 2019). Most deaths in children under 5 years are attributable to undernutrition which puts them at risk of dying from common infections (Afshin, et al, 2020). Available data sources indicate that one in every four children suffer from Vitamin A deficiency, one in every three children of the age group 6-59 months suffer from iron and only 4% of the children in Zimbabwe receive minimum acceptable diets to address malnutrition (UNICEF, 2019). According to Wessels (2012), about 48.4% of the children below 5 years are at risk of inadequate Zinc intake. Children under the age of 5 years in developing countries are very vulnerable to micronutrient deficiencies which are important for their growth and development.

Stunting in Zimbabwe is at 26% which is above the globally acceptable level of 20% and one in every two children under the 5 years suffer from hidden hunger due to deficiencies in vitamins and other essential nutrients (UNICEF, 2019). In Zimbabwe one quarter of the children below 5 years are stunted,75% suffer from Iron deficiency ,1 in every 3 suffer from Iron deficiency anaemia and 1 in every 4 suffer from Vitamin A deficiency thereby pointing to a huge malnutrition challenge (Afshin, et al, 2020). Failure to address malnutrition will not only hold back progress towards Sustainable Development Goal (SDG) 2 of ending hunger and malnutrition in all its forms but will undermine at least other11 global goals. In children under 5 years malnutrition, has profound defects that includes; delayed motor and cognitive development, it also undermines their capacity to grow, develop and learn to full potential as they eat too little of what they need most and too much of what they do not need (Pelto G.H, 2003).

Stunting in children under 5 years is a clear sign of malnutrition and reflects on past food deprivation. Malnutrition is a predictor of future poverty and the prevalence has reduced in other continents except for Africa due to poverty and other underlying causes (UNICEF, 2019). Traditional supplementary foods are mostly cereal based and are of poor nutritive value and fortifying rapoko with cowpeas will help provide a low cost source of the much-needed Proteins, Iron, Zinc and Vitamin A necessary in addressing malnutrition in children under the age of 5 years. There is very limited knowledge on value addition of cow pea and rapoko into nutritious foods as a result, smallholder households have predominantly consumed them as sole starchy and energy dense foods.

Food fortification have been primarily focussing on industrial scale as enshrined in the Zimbabwe food fortification strategy which focusses mainly on salt, flour, margarine, and sugar which are beyond the reach of marginalised households. Of the few local food fortification initiatives to date, none have used rapoko and cow pea combined as fortification vehicles, yet they have essential macro and in addressing malnutrition in children under the age of 5 years. There is also a paucity of data on the consumer acceptance of such supplementary foods and therefore it is not known whether it could be successfully used to address malnutrition. This study therefore seeks to determine the nutritional composition of rapoko, cowpeas and rapoko-cowpea fortified blends and acceptability of the developed blends for children under the age of 5 years.

1.3 Objectives

1.3.1 Main objective

Develop a low cost fortified supplementary Rapoko-Cowpea Blend (RaCoB) porridge with improved macro and micronutrient content and sensory attributes for children under the age of 5 years.

1.3.2 Specific objectives

- To determine the proximate composition of Rapoko and Cowpeas from Gokwe, Murewa and Masvingo.
- To develop different RaCoB blends and determine their nutritional composition (Vitamin A, Iron, Zinc, crude protein, crude Fat, Total ash, fibre, Energy, moisture content and carbohydrates).
- Determine acceptability of different RaCoB blends through sensory evaluation attributes (Texture, body, Colour, Appearance, Aroma, taste, and overall acceptability).

1.4 Hypothesis

- Rapoko and Cowpeas from different locations have high levels of macro and micronutrients (Vitamin A, Iron, Zinc, crude protein, crude Fat, Total ash, fibre, Energy, moisture content and carbohydrates).
- Developed RaCoB blends have high levels of macro and micronutrients that meet the recommended WHO daily dietary intake of nutrients by children under the age of 5 years.
- Developed blends RaCoB blend ratios have favourable acceptability levels based on Texture, body, Colour, Appearance, Aroma, and taste by gender.

1.5 Justification

COVID 19 does not treat us equally and undernourished children have weaker immune systems and may be at greater risk of severe illness due to the virus hence the need for low-cost products that may be used as a supplementary food to address malnutrition in children below the age of 5 years (Afshin, et al, 2020). Good nutrition is an essential Nutrition as part of an individual's defence and nutritional resiliency against COVID 19. Rapoko-Cowpea blend may help reduce childhood malnutrition and mortality by focusing on nutritional wellbeing and establishing synergies between nutrition, food security and health (UNICEF, 2019).

This study may also stimulate potential avenues for commercialization of the new product and may also generate market driven production of Rapoko and Cowpeas by small holder farmers.

Institutions that may benefit from this study include small holder farmers and input providers in this value chain who may get opportunities to get income through selling of seeds and agrochemicals.

Public and private extension staff may also identify extension gaps that may require strengthening. The study may generate debate in the academia field and generate room for further studies in areas like weight gain from consumption of RaCoB by children under the age of 5 years. Other Researchers may explore more opportunities of broadening available products from the two crops. Institutions like Universities and Non-governmental organisations may also benefit by expanding their scope of research and programming in areas like anti-nutritional factors in Rapoko, Cowpeas and how to address them. Through the findings of this research it is hoped that policy makers will benefit as they will be able to develop comprehensive policies and programs to support nutrition under the age of 5 years. Global mandatory home based food fortification has potential to improve diets for 15.6 million malnourished children under the age of 5 years (UNICEF, 2019).

Available commercial supplementary weaner foods and protein sources like meat are expensive for the rural household and low-cost supplementary product may provide a sustainably source of nutrients for children under 5 years in both rural and urban setting. Cowpeas is a good source of proteins (15-40% of crude protein) and Rapoko provides 35-60% of starch to children. These two grains have substantial amounts of iron, zinc and other macro and micro minerals necessary for a healthy body. They are also highly adaptable to semi-arid areas and can be easily grown in most regions of Zimbabwe by ordinary and poorly resourced farmers (Serere Harusekwi Julien B. B., 2016).

1.6 Delimitations of the study

This was a mixed research method study which focussed on Laboratory testing of Rapoko, Cowpeas and RaCoB that was purchased from three randomly selected vendors who source rapoko and cowpeas from three locations (Gokwe, Murewa, Masvingo) and sell at Mbare market. Laboratory nutritional analysis of rapoko and cowpea ingredients and formulated blends were done at the University of Zimbabwe Food science laboratory where there is adequate equipment for conducting Proximate analysis.

A cross sectional survey on sensory evaluation of the blends was done with a panelist of 100 volunteer students from the University of Zimbabwe Food Science department who had signed consent forms.

1.6.1 Limitations of the study

This study did not test the nutritional gains by children under the age of 5 years to determine their performance after being fed on RaCoB but relied on sensory evaluation results from 100 panelists. Consumer product acceptability evaluation was only centred on one location due to limited research time and this limits the generalizability of the research outside the study location. Also, Corona Virus disease (COVID 19) pandemic outbreak delayed laboratory tests and the final production of this study due to country lockdown and fear of contracting the deadly disease. Bindura University of Science Education gave me a clearance letter to easy my movement to UZ for laboratory experiments however security authorities would still deny me travelling even after producing the clearance letter. The researcher had to strike a balance between work and family, thus time was not sufficient and meeting deadlines was not easy. The researcher had to take some days off from work to do the research though this was somehow disturbed by the COVID19 global pandemic lockdown.

1.7 Outline of Thesis

This thesis is structured into 6 chapters which cover different aspects for easy reading and conceptualization of issues.

Chapter 1: This section looked at the background of this study with special attention on malnutrition on children under the age of 5 years. Key macro and micronutrients needed by children under the age of 5 years were discussed and special mention was done on the effects of malnutrition. An overview of malnutrition at Global and local level was also examined with the view of exposing the magnitude of the problem. Nutritional composition of Rapoko and Cowpeas was also discussed and benefits of fortifying the two. It has been noted that RaCoB is a new product on the market that may be produced at low costs using rapoka and cowpeas that are local grown by small holder farmers and are nutritional dense to support children under 5 years against malnutrition.

The chapter also managed to identify existing products on the market from Cowpeas and Rapoko and how the new product will help complement existing supplementary foods in addressing malnutrition and hidden hunger.

Existing strategies being employed in alleviating malnutrition were also looked at. The statement of the problem is anchored on addressing malnutrition for children under the age of 5 years who lack essential macro and micronutrients. Some of the available supplementary products on the market for addressing malnutrition are expensive for the ordinary and poorly

resourced citizen, leading to intergenerational nutritional challenges. The main objective of the study was to develop a low cost fortified supplementary Rapoko-Cowpea Blend (RaCoB) porridge with improved macro and micronutrient content and sensory attributes for children under the age of 5 years. Specific objectives of the study, study hypothesis, delimitation and limitations have also been highted to guide this study.

Chapter 2: In this chapter the researcher examined available literature and related it to theoretical framework. Literature on prevalence and effects of malnutrition at Global and local level was reviewed in the context of addressing malnutrition for children under the age of 5 years. Existing available Rapoko, Cowpea and other weaner supplementary foods were looked at and gaps identified which are mostly related to access, availability, and utilisation. Other studies on Proximate analysis of rapoko, cowpeas and similar blends were also reviewed with the view of identifying nutrients (macro and micro gaps) necessary for children under 5 years that can be filled by the low cost fortified RaCoB. Previous studies on sensory evaluation were also reviewed to guide blending ratios and sensory evaluation attributes necessary in checking overall acceptability of a new product by gender.

Chapter 3: The focus of this chapter was to briefly describe the study area, develop a proper research design, sampling, and data collection procedure. It is important to note that a mixed research method (experiment, cross sectional survey) was used in this study. Nutritional composition of rapoko, cowpea and RaCoB was determined through laboratory testing of the ingredients. Sensory evaluation was done through a cross sectional survey with 100 voluntary panelists of university students from UZ. Research ingredients were purchased from the biggest market (fruit, vegetables, grains) in Harare. Clustering of vendors by sources of grains and simple random selection of vendors where the raw material was purchased was done to manage varietal and geographical bias since this may have an influence on Proximate analysis of the ingredients and Rapoko-Cowpea fortified blends. Ethical considerations for the study are covered as well as a summary of the key and emerging issues in this chapter.

Chapter 4: Material, methods, Research design, Results, discussions of the nutritional content of (Vitamin A, Iron, Zinc, crude protein, crude Fat, Total ash, fibre, Energy, moisture content and carbohydrates) of rapoko and cowpeas and formulated RaCoB blends have been presented and discussed. Results of blend ratios Rapoko: Cowpeas (85:15, 75:25, 60:40) were presented and discussed with the view of getting a blend ration with the highest macro and micro nutrient

content to support nutrition for children under the age of 5 years. Notably blend ratio 75:25 has the highest nutritional content (Iron, Zinc, Vitamin A, Crude Protein) necessary in addressing malnutrition. Study conclusions and recommendations are also covered in this chapter.

Chapter 5: Material, methods, Research design, Results, discussions of the acceptability of different RaCoB blends through sensory evaluation attributes (Texture, Colour, Aroma, and overall acceptability) is covered in this chapter. It is important to note that there is statistical significance in acceptability of different RaCoB blends with blend ratio 75:25 being the most preferred across men and women.

Chapter 6: In this section the study; gives a summary of the research findings, conclusion, policy implications of the findings, recommendations, and areas for further studies. References and appendices are also presented at the end of this chapter

1.8 References

1. Afshin, A., 2020.Global Nutrition Report, 2020.
2. Pelto G.H, Levitt E, Thairu L, 2003. Improving Feeding Practices: Current Patterns, Common Constraints, and the Design of Interventions. Food Nutr. Bull., 24: 24-82
3. Serere Harusekwi Julien, B.B., 2016. Development of Fermented Corn and Rapoko Blend Instant Porridge. International Journal of Nutrition and Food Sciences, 5(4), 246.https://doi.org/10.11648/j.ijnfs.20160504.13
4. UNICEF, 2019. Children. Annual Report, For Every Child Reimagine, s. i. s. n
5. ZimVAC. 2019. Zimbabwe Vulnerability Assessment Committee. Retrieved from www.fnc.org.zw. info@fnc.org.zw
6. World Food Programme, 2006. Micronutrient fortification: WFP experiences and ways forward. Food and Nutrition Bulletin 27: 67-75.
7. Garrow, J. S. et al., 1999. Human Nutrition and dietetics,10th ed. London, Churchill, Livingstone.
8. Talsma E.F, Brouwer ID, Verhoef H, Mbera GN, Mwangi AM, Demir AY, Maziya-Dixon B, et al 2017. Biofortified yellow cassava and vitamin A status of Kenyan children: a randomized controlled trial. American Journal of Clinical Nutrition.
9. . Mukarumbwa, P., & Mushunje b, a. 2010. Potential of Sorghum and Finger Millet to enhance Household Food security in Zimbabwe's semi-arid regions, s.i.sn
10. Ravindhran, R, 2017. Biofortification in Millets: A sustainable approach for Nutritional security.
11. Awuchi, Chinaza Godswill 2019. Proximate composition and functional properties of different grain flour composites for industrial applications

CHAPTER 2
LITERATURE REVIEW

2.1 Introduction

In the previous chapter the researcher looked at the background, statement of the problem, objectives, and associated hypothesis. Informed by the identified research gap this chapter looked at justification for carrying out this study, its contribution to existing efforts in addressing malnutrition for children under the age of 5 years and how different stakeholders can benefit. Delimitation, limitations of the study and outline of the thesis are also covered. This chapter guided by the Research objectives looked at malnutrition at global and national level, its effects, Rapoko and Cowpea nutritional composition and importance of each element, existing efforts in addressing the challenge, Existing products on the market and proximate results from other studies, Sensory evaluation, Cowpeas and Rapoko production and constraints and theoretical framework guiding the study.

2.2 Understanding Malnutrition at Global and Local context

About 800 million people globally do not have access to enough food and over 2 billion individuals do experience micronutrients deficiency (Wessells, 2012). Sub-Saharan Africa has almost 200 million undernourished children due to the frequency of food crises which is caused by recurrent droughts, floods, and economic instability. About 48.4% of the Zimbabwean children below 5 years are at risk from micro and macro nutrients deficiency (Wessells, 2012). It has been recorded that 1in 3 children under the age of 5 suffers from undernutrition or overweight and 1in 2 suffers from hidden hunger which retards the growth of children to full potential (UNICEF, 2019).

Zimbabwean nutritional status has not changed much over the past 10 years and chronic malnutrition is the major challenge which is characterized by inadequate amounts of food and poor nutritional quality of the available foods, with children in rural areas affected most (Serere Harusekwi Julien B. B., 2016). Zimbabwe has over the past years been experiencing erratic rainfall and long mid-season dry spells leading to food insecurity in most of the marginal areas of the country thereby exacerbating malnutrition challenge. The main reason for under nutrition is mainly due to inadequate access to protein and energy dense foods for the daily body requirements due to poor access and poor purchasing power by poor populations. (Astuti Verma, 2019).

2.2.1 **Malnutrition and its effects among children**

Malnutrition which includes both undernutrition (lack of food energy, macronutrients like proteins, micronutrient deficiencies like Iron, Zinc and Vitamins) and over nutrition (an excess of food energy) is one of the largest causes of child mortality for the under 5 years (Beddington, (2011). Provision of adequacy dietary energy is important during the period of rapid infancy growth and childhood development and that is the reason why children under the age of 5 years are affected most. Nutritional status of the community signifies development, wellbeing of a nation and contributes to the genetic potential of children who can be productive to drive development.

Under nutrition may result in permanent physical and cognitive challenges due to inadequate intake of nutrients which are required by the body to support growth and other functions. Under nutrition in children under 5 years is most prevalent in developing countries whilst over nutrition is common in developed countries. Factors like poverty, social economic status, agriculture productivity (availability of land, global warming, conflicts, lack of resources, farming skills) are some of the noted drivers to malnutrition the age group in this study (Fredrick, M, J., 2015).

2.2.2.1 **Nutritional elements in Rapoko and their functions**

It has been noted that many developed and developing countries are underutilizing Rapoko which can be processed into value added foods and beverages. It is for celiac patients because it does not contain gluten (Devi P, 2014). All foods including Rapoko have macro and micronutrients in different levels which determine the quality of a diet to support a healthy body. Rapoko is in most cases eaten as a stand-alone food and food fortification of the two will increase nutritional composition which is necessary in addressing diet related illness in children under the age of 5 years. Rapoko provides starch, carbohydrates (dietary fibre), energy and other nutrients which are important for human diet. Rapoko is one of the most consumed food crops after maize in Africa (Ashwani K, 2018).

Rapoko is known to provide two-thirds or more of dietary calories and this attribute makes it good for children under 5 years. The crop is rich in tryptophan, cystine, methionine, micronutrients, and bioactive compounds necessary for growth and well-being of children (Onyanga,2004).The grain provides approximately 44.7% of essential amino acids, 12,8g/100g crude fibre, 4,76 -11,7g/100g crude protein and between 56,88 -72.97g/100g of Carbohydrates. (Saleh, 2013). Rapoko provides safety from diseases like diabetes because of slow release of glucose into the blood thereby reducing glycaemic load levels in the body. Rapoko grain is also known to have properties that address the following challenges: cancers, obesity,

cardiovascular diseases and may assist in inflammation and wound healing challenges and the antioxidant methanolic component of Rapoko helps in addressing ageing (Ashwani K.2018).

2.2.2.1.1 **Rapoko production**

Rapoko /Finger millet which is scientifically known as (*Eleusine coracana L)* is a drought, pests and diseases tolerant crop that grows best in semi-arid areas because of its strong adaptive advantage and lower risk of failure. Rapoko is regarded as "small seeded grass" that includes which is ranked the second staple cereal in Zimbabwe after maize in supporting food and nutrition security, although the rate of adoption is low due to several barriers (UNDP, 2018). The crop is an important cereal that grows well in semi-arid areas and is central to the provision of food and nutrition at household level in the face of climate change and perform a principal role in most diets of developing countries (Moyo ,S, 2000). Yields from Rapoko are more stable under abiotic stress conditions (high temperatures, low rainfall) and requires less nutrients during vegetation stage.

Production trends for Rapoko are difficult to interpret because of incomplete information and its production is mostly done by small-holder farmers who are constrained by issues like low yields due to poor agronomic practices and processing challenges among other issues. Growing of traditional crops like rapoko and subsequent developmental of products from them could help solve food insecurity, dietary quality and ultimately reduces malnutrition in children (Serere Harusekwi Julien B. B., 2016). Agricultural experts have picked several factors that are affecting adoption of rapoko by small holder farmers. Lack of quality seeds which force small holder farmers to rely mostly on retained seeds which are susceptible to pests and diseases was noted as one of the barriers. Government input support schemes do not include rapoko in most cases and stocking of these seeds by local agro dealers is limited (UNDP, 2018). Rapoko is favoured by quelea birds and rodents and in most cases small holder farmers do not get all the necessary extension support around best agronomic practises thereby leading to in low yields (UNDP, 2018).

2.2.2.2 Nutritional elements in Cowpeas and their functions

The whole cowpea plant can be used that is; foliage (above ground biomass) is used as livestock feed as fodder/hay and leafy greens, seeds, and pods are used for human consumption (FAO, 2011). It is also good in addressing cardiovascular and diabetes conditions. Dried seeds can be boiled or milled into flour to make fritters and other products. Cowpea seed is a good source of protein (17.4-31.7%), Fats (1-3.03%), Carbohydrates (35.7-65.7%), Insoluble fibre (1.7.5-16.6%) and minerals (2.6-4.6%) (FAO, 2011). The grain has tremendous potential for increased contribution to child nutrition in the tropics and is widely consumed in Africa, Asia, Latin

America, and Southern United States. The crop has emerged from relative obscurity to become a major component of human nutrition as source of vitamins, Proteins, Fibre, and minerals (ILechakwu, 1996).

Table 2.1: Food elements and their functions

Item	Important Sources	Functions
Crude fibre	Cereals, legumes	Polysaccharides (cellulose, hemicellulose A and B, gums, mucilage, pectin and lignin and acts as a brush that cleans the body. Fibre is good for bowl movement, increase stool weight, faecal bulk and reducing gastrointestinal transit time.
Carbohydrates	Cereals like Rapoko, Sorghum, maize	Carbohydrates provide energy that fuels children's metabolism, supports growth, keeps their brain and nervous system working and maintains overall health.
Moisture	All plant and animal foods	This is very important in maintaining shelf life of foods, thereby increasing their availability at different times of the year. It also aids in food digestibility. Food spoiling micro flora also thrives well in foods with high moisture levels.

Zinc	Meat, fish, eggs, cereals, and legumes	This is very important for growth, reproduction, and wound healing
Iron	Grain cereals, legumes, meat, spinach liver and poultry	This is a component of the red blood cell pigment and muscle.
Vitamins	Liver, dairy products, fish, oils, oranges, green vegetables, fortified margarines	Good eyesight, health skin and mucus lining of the body.
Crude Fat	This represents true fat (triglycerides) and other extractable material like sterols essential oils, and fat-soluble pigments. Plant and animal lipids are good sources	Dietary fats are consumed in the form of carbohydrates, fats and proteins and provide infants and children with essential fatty acids and fat-soluble vitamins A, B, C, D and K. They heighten the palatability of food, thereby increasing their intake. Fats contribute to neurological, immunological, and functional development in children.
Protein	Liver, fish meat, cheese, milk, eggs, green peas, pulses, soya products	They are the major functional and structural components of all boy cells. They play an important role in cellular integrity and support body maintenance and growth

Source: (Garrow et al 1999)

Table 2.2: Recommended elements for under 5 years according to WHO guidelines

Item	Daily intake
Carbohydrates in grams/day	25
Energy in MJ (Kaca)/day	7.2 (1715)
Crude Fibre in grams/day	35
Protein in g/day	19,7
Crude Fat in calories/day	1200
Iron in mg/day	5.5
Zinc in mg/day	6.5
Vitamin in RE/day	350

Source: (Garrow et al 1999)

2.2.2.2.1 Cowpea production

Cowpeas is a nutrient dense legume and an inexpensive crop to grow and can easily support the health of growing children with proteins.The crop can be grown very well in hot-to - moderate temperatures and is ideally suited to tropical lowlands and does very well in hot dry conditions. The following characteristics makes the crop more adaptable to dry regions; long taproot for extraction of water, closing of the stomata that helps in hot weather, fixation of atmospheric Nitrogen through symbiotic interactions with soil rhizobia (Moyo ,2000). Available data confirms the unique ability of cowpeas to fix nitrogen under stressed conditions and can grow in poor soils (FAO,2011). Growth, flowering, and maturity stages of cowpeas are not susceptible to day length variation and this makes the crop grow well in Africa and other semi-arid areas.

Cowpeas is a herbaceous legume crop that grows predominantly in Africa as an important affordable source of protein (ILechakwu, 1996). Africa is the leading continent in exporting and importation of cowpeas for human consumption. The continent produces about 6,740 tonnes of the grain which is above other continents like Asia and Europe. Nigeria is by a wide margin the largest producer of cowpeas and other pulses and this may inspire other African Countries to do the same (ILechakwu, 1996). Cowpeas varieties are high yielding, early maturing and can fit well in different rotation patterns as a rain fed cover crop thereby making it easy to be grown by small holder farmers (Astuti Verma, 2019). The land area devoted to cowpeas in Africa is large, but the yields are poor due to poor agronomic practises and this requires capacity strengthening of small holder farmers.

2.2.3 **Locally available initiatives in addressing malnutrition**

The Zimbabwean government informed by the Sustainable Developmental Goals (Goals) has set a comprehensive Strategy of addressing nutrition by 2030 and this is a positive move in addressing malnutrition. Children may be impacted more by malnutrition because of lack of nutritious diets and the unaffordable cost of supplementary foods especial meat whose prize is beyond the reach of ordinary people. Zimbabwe has strategies and policies aimed ameliorating the low macro and micronutrient intake in children under 5 years and these includes food and nutrition security policy, nutrition strategy, national food fortification strategy and national social protection policy (UNICEF, 2019). Resources to respond to malnutrition have been overstretched by COVID 19 pandemic and low-cost food fornications may help fill the gap.

Food fortification in Zimbabwe is focused at reducing the incidence of stunting in under 5 years through industrial food fortification by adding micronutrients and minerals to industrial processed and widely used products like Sugar and Salt (Talsma et al,2017). Mineral and Vitamin supplements are usually done through UNICEF funded projects though this has been affected by COVID 19 pandemic (UNICEF, 2019).

FAO is also playing a crucial role in addressing malnutrition through biological food fortification by improving the nutrition of food crops through agronomic practices, conventional breeding, and biotechnology. The Livelihoods and Food Security project (LFSP) being implemented in Manicaland, Midlands and Mashonaland Province of Zimbabwe is promoting Iron enriched Orange maize ZS262 and NUA45 a Zinc and Iron enriched bean (Talsma et al, 2017). The Enhancing Nutrition Stepping Up Resilience and Enterprise (ENSURE), Amalima and Feed the Future are some of projects that have been implemented in Zimbabwe with a nutrition lens. All these initiatives have been overstretched by COVID 19 global pandemic since resources are being directed towards this new challenge (Afshin et al, 2020). Rapoko- Cowpea fortification which is a low-cost initiative may help address malnutrition particularly on undernourished children below 5 years who are also at risk to COVID 19 pandemic.

2.2.4.1 **Available Cowpea products on the Market**

Cowpeas have a huge potential to stabilize food and nutrition security in semi-drier regions if production is increased and more products are developed from them. To provide nutritional requirements for children we should aim to have food systems that can deliver safe, affordable, and sustainable foods throughout the year. Value addition of cowpeas has brought numerous products that are derived from flour like, doughnuts, biscuits, pies, fried cowpea paste, rock

buns and cowpea porridge. Cowpeas has nutritional value similarly to that to beans and can be cooked and eaten as a companion dish with Rapoko or sadza. Legumes represent one of the food categories that have been used extensively as staple foods to cover basic protein and energy requirements throughout the history of humanity and have several appealing attributes including their high nutritional value, low cost and long preservation value outside the cold chain . Cowpeas is regarded as a ‘’hungry season crop’’ because it is the first crop to be harvested before other cereals crops are ready. (Astuti Verma, 2019).

The crop may contribute greatly to daily protein and vitamin intake by children under the age of 5 years. Modern products like weaning mixes, blending formulations and fortifications have been produced through technology that employs fermentation, decortication, and extrusion and this study will employ low cost methods to produce a highly nutritious blend UNICEF,2020). Cowpeas can be cooked alone, flavoured with pepper, salt and eaten as a companion dish or may be cooked as porridge in combination with rice or corn. Scientists in Ghana in 1987, produced a weaning mix from cowpeas that is being used in the industry and there is room to do more fortified products that are rich in macro and micronutrients (Ch, 2013). It is from this innovation that the concept food fortification, value addition and diversity for improved nutrition has stemmed. Small holder farmers have limited products that they produce from Cowpeas to better their nutrition besides growing the crop .Food fortification is normally done through biological and industrial processes and this research seeks to fortify rapoko with cowpeas to come up with a product named Rapoko-Cowpea Blend (RaCoB) which can be used as supplementary food for children under ages 5 years.

Table 2.3: Summary of available Cowpea products

Cowpea Food	**Description**	**Uses**
Akara	Fried cowpea	Breakfast foods and smacks
Moin-moin	Steamed cowpea paste	Lunch and dinner foods
Ewa-ibji	Boiled whole cowpea	Lunch and dinner foods
Danwake	Boiled dehulled cowpea	Lunch and dinner foods
Gbegiri	Cowpea soap	Appetizers
Adayi	Cowpea purce	Purceed baby foods
Cowpea spread	Boiled meshed cowpeas with fat and season	Spread on bread and yam
Roasted Cowpeas	Flavoured roasted cowpea	Snack food

Cowpea bread	Local bread made with cereal and cowpea flour	Breakfast, Lunch and Snacks
Cowpea cake	Cowpea used as ingredients in cakes and pies	Breakfast and snack foods
Rice and beans jollof	Boiled rice and boiled cowpeas	Food for adults
Akidi-na-oka	Dish of maize and cowpea	Food for adults
Cowpea plantain potage	Boiled cowpea and plantain	Food for adults
Cowpea Yam potage	Boiled cowpea and yam	Food for adults
Cowpea weaning food	Dehulled, boiled cowpeas supplemented to cereal-based infant foods	Infant children food

Source: (Asif et al. 2013)

2.2.4.2 Available Rapoko products on the Market

Rapoko is mostly used for beer brewing, porridge making and other products. It is key in supporting food and income security of small holder farmers.

2.4 Cowpea Proximate results from other studies

Table 2.4: Proximate and Fibre composition of Cowpea whole grain (% dry matter)

Data source	**Husain and Basahy (1998) [a]**	**Maia et al (2000) [a]**	**Rivas-Vega et al (2006) [b]**	**Carvalho et al (2012)**	**Devi, Kushwaha (2015) [c]**	**Heuze and Tran (2015) [a]**	**Yewande and Thomas (2015)**	**USD-ARS (2016)**
% dry matter	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean
Ash	3.6	3.6	3.9	3.7	4	4.1	3.7	3,39
Carbohydrates*	58.8	71	74.8	40.6	66		53.6	59.6
Crude Fibre			2.6	24.2	4.57	5.6	4.4	10.7d
Crude protein	23	22.7	26.1	20.3	27.7	25.2	23.4	23.9

Source: (Asif et al. 2013)

Table 2.5: Levels of mineral in Cowpeas whole grain in mg/g dry matter

Data s5urce	**Akinyele and akin-losatu (1991)**	**Boukar, Massane & Muranaka (2011)**	**Belane and Dakara (2012)**	**Carvalho et al (2012)**	**Heuze and Tran (2015) [a]**	**USDA-ARS (2016) [a]**
Mineral	Mean	Mean	Mean	Mean	Mean	Mean
Calcium	0.446	0.826	0.6	0.37	11	0.95
Phosphorus		5.06	4.7		4.2	4.92
Iron	16.9	5.3	6.1	6.9	42.2	11.2
Zinc	4.5	3.6	4.3	3.3	3.8	6.9

Source: (Asif et al. 2013)

2.2.5.2. Rapoko Proximate results from other studies

Proximate analysis from Ashwani, K, (2018) showed the following nutrients composition; Carbohydrates 71.52g/100g, Crude protein 7.44g/100g, fat 1.43g/100g Crude fibre 3,60g/100g, Calcium 348mg, Phosphorous 250mg and 36.6mg Zinc. Rapoko contains dietary fibre and polyphenol compounds which provides the following health benefits; delayed nutrient absorption, increased faecal bulk, lowering of blood lipids, prevention of colon cancer, barrier to digestion, mobility of intestinal contents, increased feacal transit time and fermentability characteristics. (Devi P, 2014). Rapoko Proximate results from Omoniyi, (2016) produced the following results; Moisture (8.56±0.000), protein (11.03±0.000), Crude fat (3.19±0.010), Cruse fibre (3.19±0.010), Ash (1.67±0.007), Carbohydrates (72,99±0.326), Iron (52.87±0.0005) and Zinc (10.9519±0.0019).

Table 2.6: Levels of mineral in Cowpeas whole grain in mg/g dry matter

Protein	**Crude fat**	**Ash**	**Carbohydrates**	**Iron**	**Zinc**
11.03±0.000	2.56±0.050	1.67±0.007	72,99±0.326	52.87±0.0005	10.9519±0.0019

Source: (Omoniyl, 2016)

2.2.6 Sensory Evaluation and the Role of Gender

Sensory Evaluation is a scientific discipline used to evoke, measure, analyse and interpret reactions to those properties of foods and materials as they are perceived by senses of sight, smell, taste, touch, and hearing (Lawless, H.T,2013). Food, people, testing environment and testing methods used can affect the sensory evaluation results. Sensory evaluation of food products gives the overall quality of the product through characterization and measuring of sensory attributes of products like appearance, Aroma, Texture, and sound that influence product development (Lawless, H.T,2013). Sensory testing can help pinpoint the imperative sensory characteristics that drives product acceptability. The role of the sensory attributes is discussed below.

Appearance

This is the first characteristics that is perceived by the human senses and plays an important role in the identification and final selection of food. The appearance of food can stimulate appetite or influence its depression through visual perception of food colour, shape, size, dullness and transparency because we eat with our eyes before ever smell or taste (Lawless, H.T,2013).

Flavour

This is a combination of taste and odour which is perceived by the nose and mouth feel. Odour drives the delight to eat food. Taste helps with food identification, acceptance, and appreciation by consumers. It is perceived by the taste buds as either; sweet, sour, salt, and bitter (Kemp et al. 2009).

Aroma

These are the volatile smells which are perceived by the odour receptors of the olfactory tissues of the nasal cavity. A pleasant smell makes food delicious and helps perceive it as fresh, rancid, intermittently poisonous food (Kemp et al. 2009).

Texture

This is also an imperative feature of food acceptancy which is perceived from a combination of attributes like, touch, mouthfeel, sight, and hearing (Kemp et al. 2009).

Sound

During Sensory analysis, hearing helps depicts the sound of food during preparation and ingestion senses to measure, analyse and interpret the organoleptic properties of food for its acceptancy (Kemp et al.2009).

Gender and sensory Evaluation

A study that was conducted at the Institute of Food Science Technology showed that; more men are colour blind than women and this makes women better in discriminating colours, whilst men are good at tracking fast moving objects and discerning details from a distance. Women have better odour memory and a high level of acuity for some subsistence because of more cells in the olfactory bulb than men. The study showed that men are likely to experience hearing loss as they age than women, thereby making them sensitive to sound than women. Women are superstars than men when it comes to bitter identification, sour and sweet intensity assessment and do have better oral stereognosis than men. It has been observed that more women participate in sensory panels and panel leaders in most cases are women (Oliveira-Pinto A, 2014).

2.3 Theoretical framework/s

To lay foundation for this study it is important to understand the nutritional framework in line with its multidimensional issues for purpose of developing a Rapoko-Cowpea fortified blend for children under the age of 5 years.

2.3.1 Nutritional framework

Malnutrition resulting from hunger and food insecurity has detrimental consequences like increased risk of disability, poor child development, morbidity, and mortality at individual and societal level. UNICEF,2019). Nutrition is directly related to food intake and infectious diseases such as diarrhoea and measles. This said challenges reflects on the underlying and economic conditions at household, community and national level which are supported by the political, economic, and ideological structures existing within a country (Afshin, et, al. 2020). Nutrition has multidimensional causes, effects and to a greater extent influenced by food security pillars that is; availability, access, utilisation and stability (UNICEF,2019). Nutritional status is influenced by immediate factors like food intake in terms macro and micronutrients, socio-economic factors that may lead to infectious diseases like diarrhoea and respiratory infections.

Food security which happens when all the people at all the time have physical, social, and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life is anchored on availability ,access, utilisation and stability (FAO.2011). To support nutrition, the food availability pillar should support own

entitlements, distributions, and exchange to address chronic, seasonal, and transitory food insecurity. Food access and stability are also important in supporting the utilisation pillar which is key for this study. Good nutritional is important for a health life and access to health and nutritious diet is very important for good health. Better nutrition support strong immune body systems, better health, and less illnesses. Negative externalities of under nutrition are many especially for children under the age of 5 years and this is common in developing countries due to food insecurity and other factors like poverty.

Poor child health and nutrition has long term economic and human development costs and will affect the future status of children. The theoretical framework has its origins in Becker, G, (1981) microeconomic models of production on which households allocate goods and time to production of commodities that are either sold or consumed at home. The nutritional status provides an indirect indicator of a child's health and a direct indicator of access to nutritious foods. Malnutrition is a vigorous indicator of a child's nutritional deprivation. The cause of nutritional deprivation is diverse, multisectoral and interlinked. Understanding Malnutrition, its effects, current initiatives, challenges, Rapoko and Cowpea production will help in the formulation of RaCoB blend for children below the age of 5 yeas (Becker, G,1981). The nutritional framework in this study helped in the conceptualization of malnutrition, its effects, nutrient composition of Rapoko, Cowpeas and functions of different element. Further understanding of available initiatives to address malnutrition and related literature on proximate analysis and sensory evaluation guided Rapoko Cowpea fortification. Finally, this study employed sensory evaluation to evaluate overall acceptability of their developed new product.

2.4 Summary of literature Review

Literature review has revealed that malnutrition is a challenge at global and local level despite numerous efforts being employed to address it. Over and undernutrition affects cognitive, physical development and wellbeing of children under the age of 5 years. These two grains are very much adaptable to semi-arid regions which receive limited rainfall and can grow easily in soils of poor fertility. Production of the two crops is not spared from challenges like: lack of improved varieties, extension, poor markets, and limited technology in processing. It is important to note that there are already existing products on the market from these grains which are consumed as stand-alone foods (Nyankori, J., 2002).

Proximate results from other studies confirm that the two grains are highly nutritious and may supply required macro and micronutrients for a healthy body. RaCoB is a low cost, highly

nutritiously and unique blend that can be produced easily in the country and is supported by local production. This initiative will complement other efforts that are being done to reduce malnutrition in the face of COVID 19 global pandemic which has over stretched available resources. Available literature has shown that women are very key in sensory evaluation and participate very much in such panels to give overall acceptability of new products.

2.5 References

1. Wessells, K. R., Singh, G., & Brown, K. 2012. Estimating the Global Prevalence of Inadequate Zinc Intake from National Food Balance Sheets: Effects of Methodological Assumptions. PLoS ONE. https://doi.org/10.1371/journal.pone.0050565.t003
2. UNICEF, 2019. Children. Annual Report, For Every Child Reimagine, s. i. s. n
3. Serere Harusekwi Julien, B.B., 2016. Development of Fermented Corn and Rapoko Blend Instant Porridge. International Journal of Nutrition and Food Sciences, 5(4), 246.https://doi.org/10.11648/j.ijnfs.20160504.13
4. Astuti Verma, 2019. Physico-Chemical properties and nutritional composition of improved varieties of grain cowpeas grown in pantnagar.
5. Beddington, 2011. Achieving food security in the face of climate change: summary for policy.
6. Fredrick, M, J., 2015. Assessing and addressing global nutrition. Jama 313 (3) 232.
7. Devi P, V. R. 2014. Health benefits of Finger millet (Eleusine Coracana L. Polyphenols and dietary Fabre. Improving Feeding Practices: Current Patterns, Common Constraints, and the Design of Interventions. Food Nutrition. Bull., 24: 24-82.38. Pelto G.H, Levitt E, Thairu L
8. Ashwani, K., 2018, Millets: A solution to agrarian and nutritional challenges. Research Gate
9. Onyango, C. 2004." Proximate Global composition and digestibility of fermented and extruded uji from maize-finder millet blend'' LWT food Science and Technology
10. United Nations Development Program Report, 2018.
11. Moyo, S., 2000. Zimbabwean environmental dilemma: balancing resource inequalities. Harare, Zimbabwe Research organization.
12. Food and Agriculture Organization of the United Nations, 2011, FAO book production Rome, Italy
13. ILechakwu, E.N. (1996). Cowpeas production.
14. . Garrow, J. S. et al., 1999. Human Nutrition and dietetics,10th ed. London, Churchill, Livingstone.
15. Talsma E.F, Brouwer ID, Verhoef H, Mbera GN, Mwangi AM, Demir AY, Maziya-Dixon B, et al 2017. Biofortified yellow cassava and vitamin A status of Kenyan children: a randomized controlled trial. American Journal of Clinical Nutrition.
16. Afshin, A., 2020.Global Nutrition Report, 2020.

17. Ch, M. 2013. Utilization of common grain crops in Zimbabwe. African Journal of Food Science, 7(9), 253–257. https://doi.org/10.5897/ajfs2013.1011
18. Asif M.L. W. Rooney. Ali and M.N Riaz ,2013.''Application and opportunities of pulses in food system: Review'', Critical Reviewers in Food science and Nutrition.
19. Omoniyl A, A. A., 2016. A Proximate analysis and mineral compositions of different cereals available in Gwagwalada market, F.C.T, Abuja. Journal of advances in food science and Technology.
20. Lawless (2013). Laboratory exercise for Sensory Evaluation. Springer, New York.
21. Kemp et al. 2009. Sensory Evaluation. A practical Handbook, s. l. s. n.
22. Oliveira-Pinto A. V., et. al. 2014. Sexual Dimorphism in the Human Olfactory Bulb: Females Have More Neurons and Glial Cells than Males. PLOS One, Volume 9, Issue 11.
23. . Becker, G, 1981. A Treatise on family. Cambridge, Mass; Harvard University Press.
24. Nyankori, J. 2002. Product life cycle model of Cowpeas based products in Ghana. Department of agricultural and applied economics. Chemson University, Clemson, SC. USA

CHAPTER 3
METHODOLOGY

3.1 Introduction

In the previous chapter literature review was done on Rapoko and Cowpeas. It is important to note that these crops are commonly grown by small holder farmers in Africa and are good sources of micro and macro nutrients which may help address hidden hunger. Malnutrition is the major cause of child mortality, poor physical and cognitive development. Blending of the rapoko and cowpeas may produce a highly nutritious product necessary in the provision of nutrients necessary for child growth and body functions. This chapter looked at the research design, study area, data collection methods, target population, sampling techniques, data collection instruments, research timeline, data analysis methods and presentation and ethical considerations in the study.

3.2 Description of study site

This study was carried out at the University of Zimbabwe (UZ) Laboratory for the (Department of Food, Nutrition and Family science) where there are proper facilities for proximate and micro nutrients analysis of Rapoko, Cowpeas and RaCoB .The new product was further subjected to sensory evaluation with the University students in the same department to check on its overall acceptability.

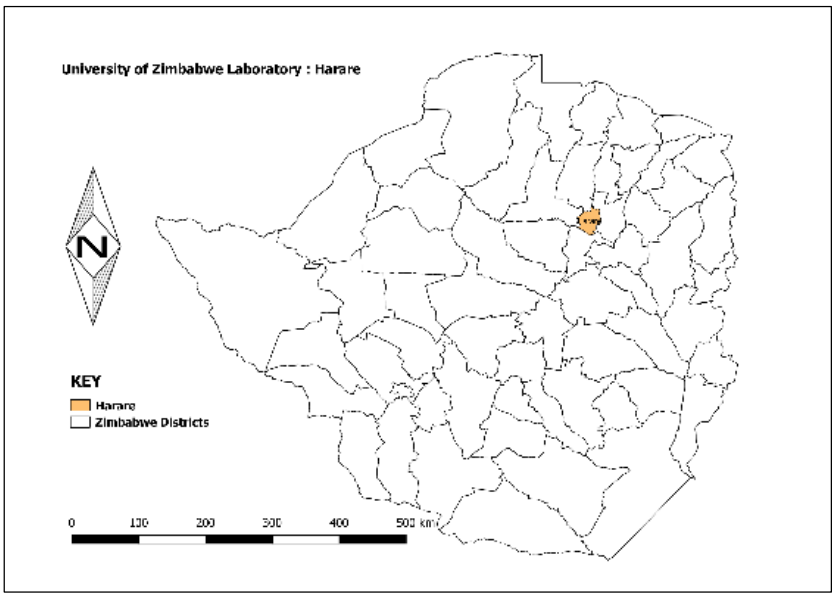


Figure 3.1: University of Zimbabwe Laboratory

3.3 Research design

A mixed method approach research was used in this study as it employs both qualitative and quantitative approach). Quantitative research was used to conduct laboratory Proximate analysis of Rapoko and Cowpeas that was randomly purchased from three vendors at Mbare Market. Further analysis was done on formulated blends to arrive at meaningful conclusions on their nutritional composition. Rapoko, Cowpeas and RaCoB blends were all subjected to proximate and mineral analysis. Rapoko proximate and mineral results were used as a control in this study. Reference was made to proximate results from other studies and WHO macro and micronutrients daily intake during sensory evaluation to check on whether the nutrients content was sufficient to meet daily nutrients requirement for children under 5 years. It is important to note that this study was focused on target and market driven Rapoko-Cowpea fortification with the view of getting a highly nutritious blend to address malnutrition.

3.3.1 Controlled experiment

A single factor Completely Random Design (CRD) was used to conduct proximate analysis of the ingredients and blends. The crop was used as a factor with Rapoko and Cowpeas as factor levels and nutritional composition as dependant variables. The experiment had three treatments which were the rapoko: cow pea ratios which were replicated three times. A total of 5kg of each of the two grains was cleaned, graded, and milled into flour. Three replicate samples for both Rapoko and Cowpeas were constituted and tested in triplicates for macro and micronutrients. Further testing was done on composite samples in triplicates to increase data reliability and reduce uncontrolled variation. Blend mixtures (85:15, 75:25, 60:40) which were informed by previous studies that used the same blending ratios (Ch, M. (2013) were formulated and tested in triplicate.Laboratory apparatus were thoroughly cleaned and calibrated to increase data validity. Blending ratios from other studies were reviewed to increase concurrent validity. Blend results were compared to rapoko nutrient content as a control.

Table 3.1: RaCoB blends used in this study

Blend	Ratio
RaCoB 1 (Rapoko: Cow pea)	85:15
RaCoB 2 (Rapoko: Cow pea)	75:25
RaCoB 2 (Rapoko: Cow pea)	60:40

Source: (Ch, M. (2013)

3.4 Population and Sampling procedures

3.4.1 Experimental procedure:

A total of 5kg of each of the two crops was randomly sourced from Mbare market which is the biggest fruit, cereal, pulses, and vegetable local market in Harare. Clusters of major Cowpea and Rapoko supplying locations was done (Masvingo, Murewa and Gokwe). One vendor was selected through simple random sampling from each cluster from a population of 5 vendors who were selling both grains. A digital scale was used during purchasing of 1.666kg of Rapoko and Cowpea grain respectively from each selected vendor in the cluster to constitute 5 kg of both grains. Cluster sampling was used to address the issue of uncontrolled variation due to variety and growing conditions of the two grains. Rapoko and Cowpeas composite samples were carried to UZ and stored in plastic bags until further analysis. The composite samples were cleaned, graded to remove any extraneous material, discoloured and decayed grain before milling them into flour. Proximate and nutritional analysis were done in triplicates on flour from both grains to reduce errors and bias.

3.4.2 Sensory evaluation

The cross-sectional study design was adopted to conduct the sensory acceptability evaluation. A total of 100 panellists were used with 30 trained and 70 untrained.From a total of 150 students from the department of Food science at university of Zimbabwe (Department of Food, Nutrition, and family sciences), a sample of 100 panelists were selected through simple random sampling. A total of 150 pieces of paper were cut to equal sizes and put in a hat with 100 papers written yes and 50 coded no. The coded pieces of paper were thoroughly shaken, and all the students were asked to draw a piece of paper without replacing it. A total of 100 students who picked papers written yes constituted the sensory evaluation panelists who were requested to sign consent forms after receiving full explanation on the purpose of the study. A sensory evaluation tool was designed, and pilot tested with 10 randomly selected students from a total of 150 students using the same method as that of selecting panelists.

Pilot testing was done to check on the required time to administer the questionnaire and whether it was capturing all the sensory quality factors. The questionnaire was used to evaluate acceptability of thin porridge from three RaCoB blends using blends; (85:15, 75:25, 60:40) as informed literature from other studies (Ch, M. (2013). The flour was tested by weighing, adding water, heating for 10 minutes in a stainless pot to avoid contamination, and adding salt/sugar when porridge was ready for eating. From a total of 100 panelists 30 panelists were trained on

the evaluation process and objective of the study and 70 were not trained. RacoB thin porridge was evaluated using a 5-point hedonic scale which employs the following scale factors; Liked extremely (5marks), Liked moderately, (4 marks) Neither liked nor disliked (3 marks), Disliked moderately, (2 marks), Disliked Extremely (1 mark). Panelists were provided with an evaluation sheet to score the three RacoB blends for the following Sensory Quality factors; Colour and Appearance, Taste/Aroma, Body and Texture and overall acceptability of the new product. This sensory evaluation method is sometimes referred to as same/difference test which allows panelists to conclude whether there are difference or not in sensory factors.

3.4 Sampling procedure

Cowpea Flow diagram

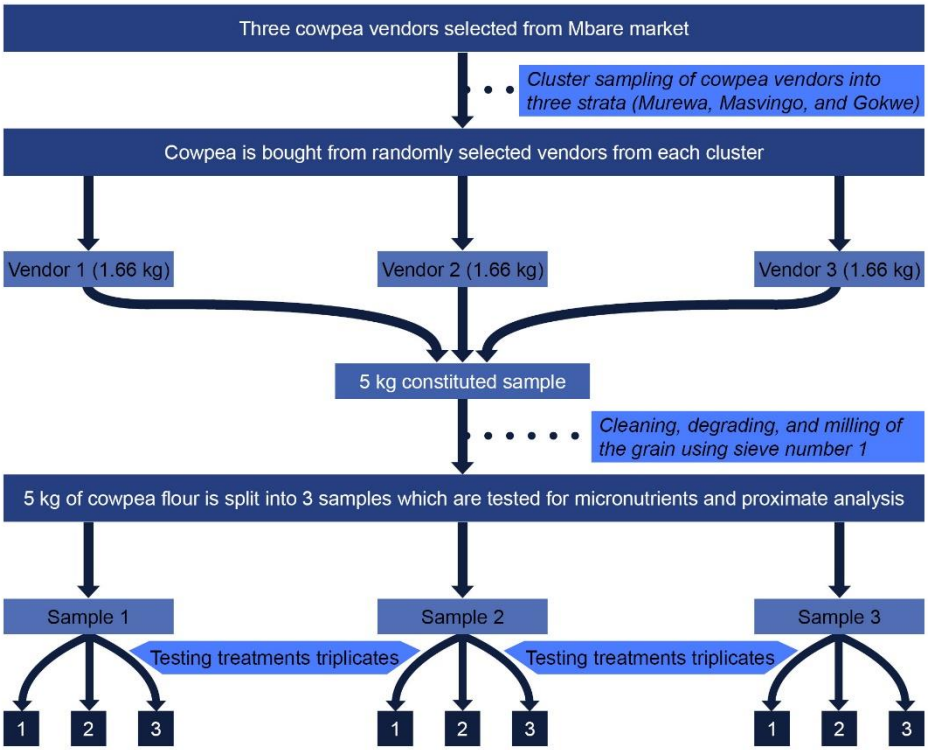


Figure 3.2: Cowpea Flow Diagram

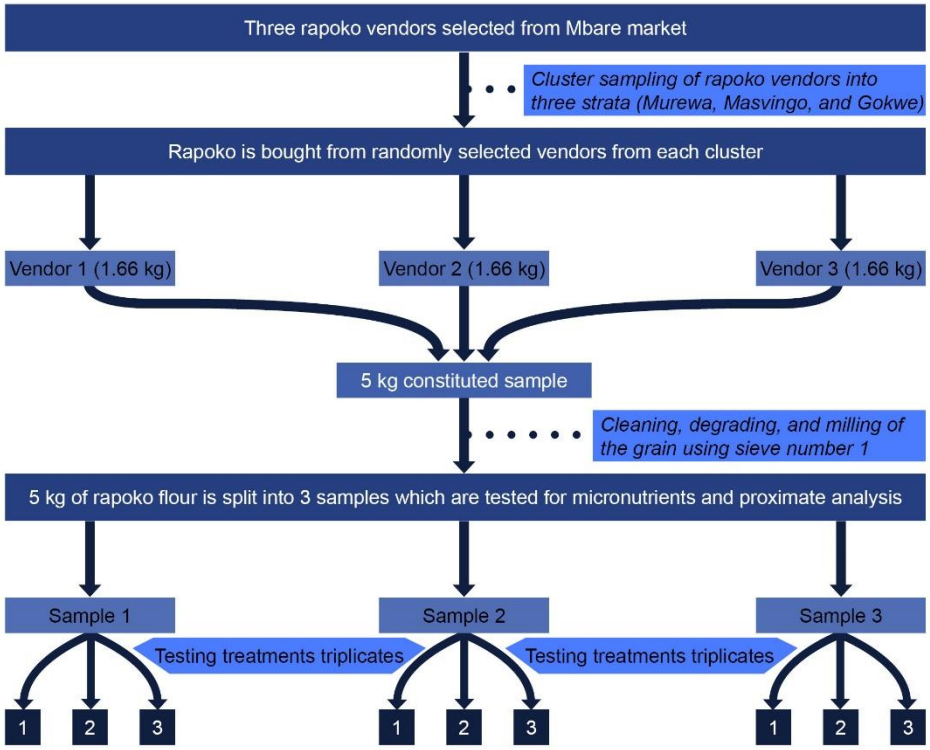


Figure 2.3: Rapoko Flow Diagram

3.5 Data collection procedure

3.5.1 Controlled experiment

Data collection sheets from laboratory proximate analysis of Rapoko, Cowpeas and RaCoB were captured in SPSS. The data was analyzed using One-way Analysis of Variance (ANOVA) and Fisher's Least Significance Difference (LSD) was used for mean comparison (Post-hoc tests). This analysis was done at 5% significance level. Descriptive statistics were also used to depict the results.

3.5.2 Sensory evaluation

Data on acceptability was collected using questionnaires and was captured electronically using the Statistical Package for Social Sciences (SPSS). This data was analysed using non-parametric tests since the data could not meet the assumptions of parametric ANOVA. Hence Kruskall-Wallis test was used, and mean separation was done using LSD at 5 % significance level. for nutritional composition and acceptability of Rapoko, Cowpeas and RacoB using Statistical significance $p<0.05$ were done and generated data was presented using graphs and tables.

i) Proximate analysis

Determination of moisture content in Cowpea, Rapoko and RaCoB

The moisture content was determined using Standard methods by Association of Analytical Chemists (AOAC) method (Omoniyl A, 2000). The evaporating dishes and lids were thoroughly cleaned by soaking overnight in 0. 1N Nitric acid and rinsed in deionised water and then dried in the oven at 105^0C for 3 hours. Then evaporating dishes and lids were transferred into a desiccator to cool. The empty dishes and lids were then weighed on a top loading balance to the nearest (0.01g decimal place).

About 5g of each of Cowpeas and Rapoko samples were weighed into the evaporating basins in triplicates. The samples were then spread to uniformity and air-dried at room temperature for 2 hours. Then evaporating dishes with samples were then placed in the oven and dried for 8 hours at 60^0C. After drying the evaporating dishes were transferred with partially covered lids to the desiccator to cool. The evaporating dishes and their dried samples were reweighed until a constant weight is achieved**.**

Calculation of moisture content

$$(\%)\ \text{moisture} = \left[\frac{W1 - W2}{W1}\right] x100$$

Where w_1 = Weight (g) of original sample

w_2 = Weight (g) of sample after drying

Determination of ash content in Cowpea, Rapoko and RaCoB

The ash content was determined using the AOAC method (Omonlyl A, 2000).The crucibles and lids were soaked in 0.1M Nitric acid overnight, cleaned and washed with deionised water and then placed in the furnace at 550^0C overnight to ensure that impurities on the surface of crucibles were burnt off. This was followed by cooling the crucibles in the desiccator for 2 hours. After cooling, the crucibles and lids were weighed to 2 decimal places. About 5 g of sample were weighed into the crucibles followed by heating over low Bunsen flame with lid half covered.

This was done in a fume hood. Then crucibles and lids were placed in the furnace until fumes were no longer existing. The samples were then heated at 550^0C overnight. During heating the crucibles were not covered with the lid. The lids were placed after complete heating to prevent loss of fluffy ash. The samples were cooled down in the desiccator. The ash with crucibles and lids were weighed after the samples turned grey. For those which were not turn grey, the ash, crucibles and lid were returned to the fume hood for further ashing.

Calculation of Ash content

$$\text{Percentage (\%) ash} = \left[\frac{\text{weight of ash}}{\text{weight of original sample}}\right] \text{x}100$$

Calorimetric determination of available carbohydrates in Cowpea, Rapoko and RaCoB by DNS method

The carbohydrate content was determined using the AOAC method (Omoniyi A, 2016). Samples 1.0g in triplicates per sample were weighed into clean dried boiling tubes on an analytical balance to the nearest 0.001g. This was followed by adding 10ml of 1.5M Sulphuric acid and the mixture was boiled on a water bath for 20 minutes with occasional stirring to hydrolyse non-reducing sugars After cooling, 12ml of 10% sodium hydroxide was added and mixed well.

The resultant solution was then filtered into a 100ml volumetric flask and the tube contents were washed into the flask using distilled water and made up to the mark with deionised water. The solution was then mixed well by repeated inversion. Ten ml of this solution was diluted to 250 ml with deionised water in a volumetric flask and mixed well by repeated inversion Standard glucose solutions of 0.25, 0.5, 1.0, 1.25 and 1.5mg glucose per ml were made by diluting the stock glucose solution containing 10mg/ml using 100ml volumetric flasks and deionised water.

A blank was prepared by pipetting 2.0 ml deionised water into a test tube and adding all the other reagents except the sample. To each of the other 5 labelled test tubes, 1.0 ml of each prepared standard glucose (0.25, 0.5, 1.0, 1.25 and 1.5) was added. Then to each of the six tubes 1ml of DNS (prepared by dissolving 10g of 3,5-dinitrosalicylic acid (DNS) in 200ml 2M NaOH with warming and vigorous stirring. Sodium potassium tartrate tetrahydrate (300g) was dissolved in 500ml distilled water (colour stabiliser).

The two solutions were mixed and made up to the mark in 1L with deionised water). All the tubes of the hydrolysate and the sample were heated in a boiling water bath for 5 minutes to allow the reaction between glucose and DNS to occur. The tubes were cooled, and the volume was adjusted to 20 ml with deionised water using a burette and mixing well. Absorbance of each solution was measured at 540nm and a calibration graph of absorbance against concentration was obtained. The carbohydrate concentrations of the samples were extrapolated from the graph and converted to % carbohydrate

Determination of crude fat in Cowpea, Rapoko and RaCoB

The crude fat content was determined using the AOAC method (Omonlyl A, 2000). Clean glassware was rinsed with petroleum spirit, dried in an oven at 102ºC for 30 min. and cooled in a desiccator. Clean, dry 250ml round bottomed flasks were accurately weighed on a top loading balance to the nearest 0.01g and about 150ml petroleum ether was put inside the flask. Dried samples about (5 g) were accurately weighed into the thimble and transferred into the Soxhlet extraction unit. Cotton wool was placed on the top of the thimble to prevent the sample from coming out. The extraction unit was assembled over an electric heating mantle. Then petroleum ether (boiling point 60-80^{0}C) was heated in the flasks until it boiled.

The heat source was adjusted so that solvent dripping from the condenser into the sample chamber achieved the rate of about 6 drops per second (Temperature set 30^{0}C). The extraction was continued for 6 hours in a fume hood. Then the extraction unit was removed from the heat source and the extractor and condenser detached. This was followed by removing the flask from the heat source and the solvent evaporated off on a rota vapour (the solvent was distilled and recovered). The flask and its content were then placed in an oven at 102ºC (operation conditions 102ºC± 1^{0}C). The contents were then dried until a constant weight was reached (1-2 hours). Then the flasks were cooled in a desiccator followed by weighing the flask and contents.

Calculation of crude fat content

$$(\%)\ \text{Crude Fat} = \left[\frac{W3 - W2}{W3}\right] x100$$

w_2 = Weight (g) of sample after drying

w_3 = Weight of original sample

Determination of crude protein content in Cowpea, Rapoko and RaCoB

The crude protein content will be determined using the AOAC (2000) method. Samples of 1.0g were be weighed in triplicates and placed in digestion flasks to which 5 g of Kjeldahl catalyst (prepared by mixing 9 part of Potassium (K_2SO_2) with 1 part of Copper Sulphate -$CuSO_4$) was added followed by 25ml of concentrated H_2SO_4). A blank was prepared in triplicate by using 5 g of Kjeldahl catalyst and adding 25 ml sulphuric acid without the inclusion of a sample. Flasks were then placed in inclined position and gently heated in a fume hood until unit frothing ceased. Boiling was briskly done until solution clears.

The flasks were then immediately connected to digestion bulb on condenser and with a tip of condenser immersed in standard acid and 5-7 drops of mix indicator (100ml of 0.1% methyl red was mixed in 95% ethanol with 200ml of 0.2% bromocresol green in 95% ethanol) in a receiver. The flasks were rotated to mix content thoroughly, followed by heating until all ammonia (NH_3) was distilled. Then the receiver was removed, the tip of condenser washed and then titrate excess standard acid distilled with standard NaOH solution.

Calculation of crude protein content

(%) Crude Protein = $\left[\frac{(A-B}{W}\right]$ x Nx6.25x100

Where A = volume (ml) of 0.2N HC L used sample titration.

B = Volume (ml) of 0.2N HCL used in blank taken

N = normality of HCL

W= weight (g) of sample

6.25 = the protein nitrogen conversion factor for vegetable and vegetable products

The crude fibre content will be determined using the AOAC method (Omonlyl A, 2000). Samples were milled to pass through No: 30 sieves. About 2g of samples were weighed accurately in triplicates to 2 decimal places on a top loading balance. The samples were extracted with petroleum free from fat on a Soxhlet apparatus. Then the samples were transferred to 1 L flasks. Diluted Sulphuric acid 1.25 %(w/v), 200ml was taken into a beaker and brought to boil. Then the boiling acid was transferred to the 1L flask. The flask was then

connected to the water, cooled, and refluxed with the condenser and heated for the contents to boil within a minute.

The boiling was continued for 30 minutes. Then the flask was removed, and the sample filtered through a Whatman No: 54 grade filter paper held in a funnel. The insoluble matter was then washed with boiling water until the washings were free from acid. Sodium hydroxide (200ml), 1.25% was boiled under a reflux condenser. Then the residue was washed on the filter paper back on the original flask by means of a wash-bottle containing 200ml of boiling sodium hydroxide solution. The flask was immediately connected with the reflux condenser and boiled for exactly 30 minutes. The flasks were then removed from the heat and allowed to stand for 1 minute. Samples were immediately filtered under suction pump through a Whatman number 54 grade filter paper.

The whole of the insoluble material from the filter paper was transferred by means of boiling water. It was then washed with first boiling water and then with 1% (2ml) hydrochloric acid and finally with boiling water. This was followed by washing with twice ethanol (10ml per wash) and three times with diethyl ether (10ml per wash). The insoluble matter was transferred to the porcelain crucible using a wash bottle containing boiling water. The water was then evaporated off on a water bath. The crucible and the residue were then dried in an oven at 105^0C to a constant weight (for about an hour). The contents were then cooled in a desiccator to room temperature and weighed. This was followed by incinerating the residue in the crucible in the electric muffle furnace at 500^0C until all the carbonaceous matter were burnt (3 hours). The temperature could come down to 200^0 and then the samples were transferred to a desiccator using tongs for further cooling, followed by weighing.

Calculation of crude fibre content for Rapoko, Cowpea and RacoB

(%) Crude fibre = $\left[\frac{(W3 - w2}{W3}\right]$ x 100

W_2 = Weight of sample after incineration

W_3 = Weight of original sample.

Crude fibre was determined in triplicate

Gross Energy determination for Rapoko, Cowpea and RacoB

This formula was used to calculate Rapoko, Cowpea and RacoB energy

Energy in (Kcal) = 4 x protein value+ 4x carbohydrate value + 9 x fat value

Proximate, Mineral and Vitamin Analysis

Proximate assay which is regarded as the best method of determining the composition and nutritional status of any ingredient intended to be used as food was used. All reagents and standard stock solutions used was of analytical grade. Water was purified by double distillation. Nitric acid used for soaking glassware and hydrochloric acid used for digesting samples was procured from Sigma Aldric. All glassware was washed with double distilled water, soaked in 10% nitric acid overnight, and rinsed with double distilled water and then air-dried.

Mineral composition analysis

The metals in Cowpea, Rapoko and RacoB were measured by inductively coupled plasma atomic emission spectrophotometry (ICP-OES) (Model ICAP 6000, Thermo-Fischer Scientific). The samples were milled to fine powder and transferred to 100ml beakers. About 2g of homogenized samples were weighed into a 200ml beaker and 10ml conc. HNO_3 was added. The beakers were covered with watch glasses and left to digest overnight. The samples were then heated on a sand bath with boiling until a clear solution was obtained. Then solution could cool, filtered, and transferred into a 50ml volumetric flask and then diluted to the mark with deionised water. The standard stock solutions with concentration of 1000mg/L all the minerals were used. Working standards for the metals were prepared by serial dilution of the standard solutions. Certified Standard Reference Material provided by Institute for Reference Materials and Measurements of the European Joint Research Centre were used for method and results validation.

Determination of Vitamin A in Cowpea, Rapoko and RacoB

Vitamin A was measured using the method below: Duplicated aliquots of 200 µl of distilled water for blanks, standard solution, a control serum, and unknown samples were placed in appropriate test tubes. Then, 200 µl of alcoholic KOH was added to all test tubes and well mixed on the Vortex mixer for 10-20 seconds. The test tubes were placed in a water-bath at approximately 55-60 °C for 20 min. A 1:1 mixture of xylene kerosene was added while the samples were saponifying in the water-bath; then, to the cooled samples 200 µl of the xylene kerosene mixture was added. Retinol was extracted by vigorous mixing of each tube on the Vortex for at least 30 seconds and centrifugation for 5 minutes.

The xylene-kerosene supernatant was withdrawn by means of a constriction micropipette connected to a rubber tube. The sample extracts were placed in spectrophotometer cuvettes and optical absorbance was recorded at 328 nm for retinol and 460 nm for total carotenoids. Samples and blanks were transferred into glass tubes for 35-min irradiation using an ultraviolet source. Retinol (µg/dl) = A0 (328) - A1 x 637 Carotenoids (µg/dl) = A0 (460) x 480 where A0 = initial optical absorbance reading A1 = optical absorbance after UV irradiation. (637 and 480 are constants) (A.O.A.C.2000).

Data Reliability

Tests for data reliability were done by carrying out experiments for reliability by checking consistency of the results. Calibration of laboratory apparatus was done as well as standardisation of reagents to ensure data validity. To minimize microbial contamination and ensure error minimization, utensils and instruments were thoroughly sterilised by using double distilled water and 10% nitric acid during processing and laboratory testing of the product.

Table 3.2: Data Analysis Methods

Parameter	Identifier	Reference
Moisture (g/100g of sample)	Method 924.06 (37.1.10)	BMF 140
Ash (g/100g of sample)	Method 923.03 (32.1.05)	BFM126
Crude fat (g/100g of sample)	Method 920.39 (A)	BMF130
Crude Fabre (g/100g of sample)	Method 978.10	BMF 133
8Carbohydrates (g/100g of sample)	Method:995.13	
Crude Protein (g/100g of sample)	Method 990.03	BFM 153

Parameter	Method	Reference
Zinc (mg/100g)	Atomic Absorption Spectro photometer (AAS)	AOAC. 2000
Iron (mg/100g)	Atomic Absorption Spectro photometer (AAS)	AOAC. 2000
Energy (kcal)	Calculation (protein, Fats, Carbohydrates)	-
Vitamin A mcg RAE	High performance liquid chromatography (HPLC)	AOAC. 2000

Methods used for Analysis (AOAC, 2000)

Product development method

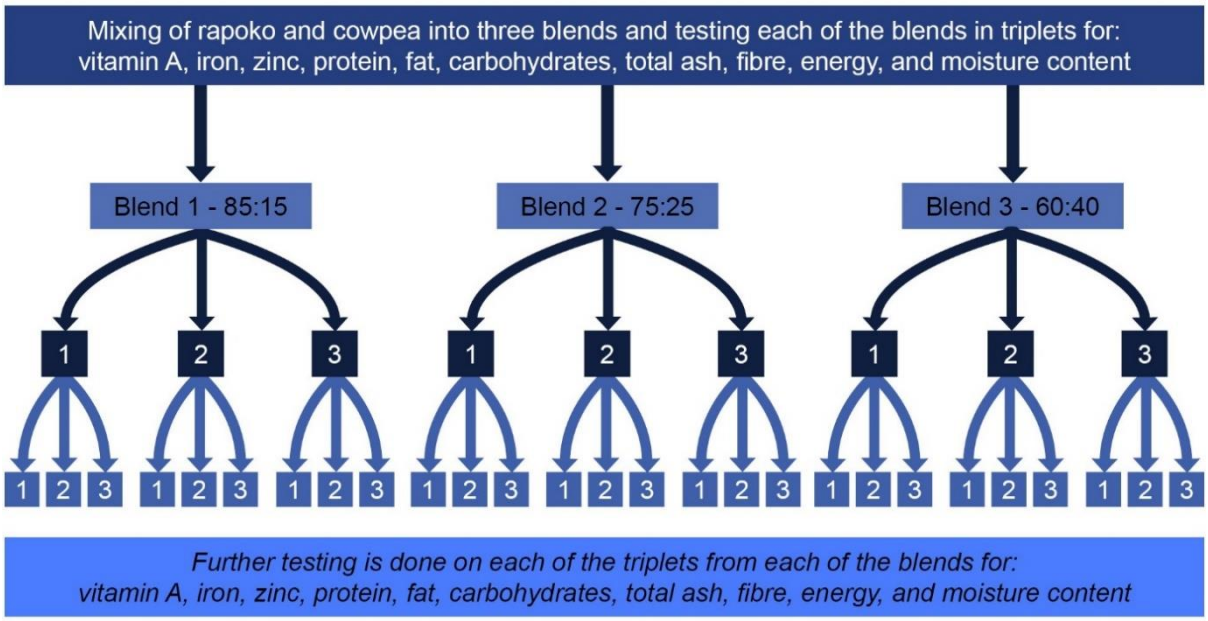


Figure 3.4: Product Development Methods

3.7 Ethical considerations

Ethics is a system of moral values, principles and attitudes that justify behaviour and are necessary in Research (Pilot ,1999). Due care was therefore taken to ensure that human rights, privacy, and confidentiality of information from all respondents in this research were done. The research was conscious of ethical concerns during planning, laboratory analysis and publishing of research. During planning attention was given to issues of scientific validity, research methods and fair subject selection through proper sampling to avoid inclusion and exclusion errors. This study used clusters and simple random sampling to purchase Rapoko and Cowpeas from Mbare market. During this study, due respect was given to respect, consent, and protection issues.

This study sought consent of the panelists by requesting them to sign consent forms before administration of sensory evaluation questionnaires. The consent form covered issues to do with their willingness to create time for the interviews and provide the required information. No penalty was levied for panelist who would want to withdraw from the evaluation. No financial rewards were promised and coercion of the to the sensory evaluation panellists was done. Explanations were done to the participants about the purpose of the study and how they were also going to benefit from the research findings and recommendations. Panelists also signed indemnity forms in case the porridge was going to affect their health.

Names of the panelist were not written on the questionnaires as a way of ensuring confidentiality. Evaluation forms were just pre-coded with numbers.

To avoid plagiarism, this research recognized and put references of all intellectual property and sources consulted. The researcher purchased research ingredients from Mbare market and conducted both the experiment and cross-sectional sensory survey to avoid falsification of data. Information from analysed data was presented without manipulation or fraud and is retrievable at any given time for use and verification.

3.8 Summary

This chapter has discussed suitable research approach, data collection methods, sampling techniques and data analysis plan for this study. The researcher designed a sensory tool that was used to evaluate sensory factors on a 5-point hedonic scale (Colour and Appearance, Taste/Aroma, Body and Texture and overall acceptability).

3.9 References

1. Polit, D. F., & H, B. P. 1999. Nursing research: Principles and methods. Philadelphia: JB Lippincott Company.
2. 19. AOAC, 2000 Official Methods of Analysis. 17th Edition, The Association of Official Analytical Chemists, Gaithersburg, MD, USA. Methods 925.10, 65.17, 974.24, 992.16.
3. Omoniyl A, A. A., 2016. A Proximate analysis and mineral compositions of different cereals available in Gwagwalada market, F.C.T, Abuja. Journal of advances in food science and Technology
4. Ch, M. 2013. Utilization of common grain crops in Zimbabwe. African Journal of Food Science, 7(9), 253–257. https://doi.org/10.5897/ajfs2013.1011

CHAPTER 4

Proximate composition of Ingredients: Rapoko and Cowpeas and Rapoko-Cow pea (RaCoB) blends

Abstract :The study results show that elements composition from characterization of Rapoko and Cowpeas are statistically significant at p -value <0.001 meaning to say they are critical elements that needs to be considered when one is doing food fortification since this varies with location due to factors like agronomic practises and genotype. The element with the most significance is Crude protein with a value of 38 191.88 and Vitamins being the least with an F-value of 0.83. There is more Crude protein in Cowpeas than Rapoko and the available zinc and iron levels may help address malnutrition challenges in children under 5 years. Proximate result shows that these two ingredients have high levels of nutrients to support daily nutrient intake by children under the age of 5 years in line with WHO recommended intake (Garrow et al, 1999).

Fortification of Rapoko with Cowpeas in the stated proportions produce a highly nutritious product that provides the required macro, micronutrients, and sensory acceptability. The macro and micronutrients nutrient in the formulated blends are higher than those in rapoko. Blend ratio (75:25) has the highest Crude fibre, carbohydrates, Protein, Zinc, Iron, energy, and Vitamins with blend (85:15) having the lowest nutritional content. This study has confirmed that rapoko and cowpeas have high nutritional composition necessary in addressing malnutrition. Fortifying rapoko with cowpea gives high levels of key nutritional elements that are necessary in addressing malnutrition in children under the age of 5 years. Sensory evaluation was informed by other studies in terms of blending ratios and sensory attributes.

Keywords: Rapoko, Cowpeas, P-Value, F-Value. nutritional content

4.1 Introduction: This chapter presents rapoko, cowpeas and RaCoB results and discusses them. There is statistically significant difference in nutritional composition in rapoko and cowpea flour sources from different by locations. The two grains have high nutritional content to meet daily requirements for children under the age of 5 years. RaCoB blend 75:25 has the highest nutrition content when compared to other blends making it the most ideal rapoko cowpea fortified blend to provide macro and micronutrients necessary for addressing malnutrition in children under the age of 5 years.

4.2 Material and Methods: Refer to Chapter 3

4.2.1 Description of study area: This study was carried out at the University of Zimbabwe Food Science laboratory. Raw material was purchased from Mbare market, which is the biggest market for fruits, vegetables that are sourced from different regions of the country.

4.2.2 Research Design: A mixed research which employs quantitative and cross-sectional survey was used in this study. In this chapter quantitative laboratory experiment was carried out for proximate analysis of rapoko, cowpeas and RaCoB flour at the University of Zimbabwe Food Science department. The nutritional content of Rapoko, Cowpeas and RaCoB was analysed in triplicates to manage uncontrolled variation.

4.2.3 Sampling procedure: Rapoko and Cowpea vendors were put into three clusters namely Gokwe, Murewa and Masvingo. A list of 15 vendors across the clusters selling both Rapoko and Cowpeas was developed, and names written on small pieces of paper. The small pieces of papers with vendor names were put in a hat and thoroughly shaken before one vendor was asked to pick three names without replacement from a population of five vendors in each cluster. Purchases of equal proportions of both grains were made from three selected vendors in each cluster using digital scale. A composite sample (5kg) was constituted, carried, and stored in plastic bags before analysis at UZ. The ingredients were cleaned by removing discoloured and decayed grain as well as removal of extraneous material . Rapoko and Cowpeas were replicated into three sub samples and tested in triplicates. Further tests were done on the composite samples in triplicates. RaCoB blends Rapoko: Cowpeas (85:15,75:25,60:40) were formulated and analysed in triplicates to reduce uncontrolled variation.

4.2.4 Data collection procedure: Data collection sheets from laboratory proximate analysis of Rapoko, Cowpeas and RaCoB were captured in SPSS for analysis.

4.2.5 Data analysis procedure: The data was analysed using One-way Analysis of Variance (ANOVA) and Fisher's Least Significance Difference (LSD) was used for mean comparison (Post-hoc tests). This analysis was done at 5% significance level. Descriptive statistics were also used to depict the results.

4.2.6 Challenges encountered during data collection: The prize of both grains was pegged in United States Dollars and this was expensive. Developing a list of vendors by location was difficult because of social distancing due to COVID 19 pandemic. This pandemic further caused delays in laboratory of analysis of rapoko, cowpeas and blends. COVID 19 WHO

standard Operating procedures guided purchase of the ingredients and laboratory analysis of the flours. A clearance letter from the University helped in managing travel movements during lock down.

Table 4.1: Macro and Micronutrient content of Rapoko and Cowpeas / Dry matter basis

Element	Cowpeas_ Murehwa	Cowpeas_ Masvingo	Cowpeas_ Gokwe	Rapoko_ Murehwa	Rapoko_ Masvingo	Rapoko_ Gokwe	P-value	F-value
Moisture (g/100g)	9.30±0.34[a]	9.10±0.048[b]	9.11±0.022[b]	3.11±0.027[c]	3.11±0.019[c]	3.061±0.020[c]	<0.001	4 960.46
Ash (g/100g)	3.67±0.047[a]	3.61±0.025[b]	3.64±0.018[c]	1.84±0.024[d]	1.88±0.027[e]	1.83±0.021[d]	<0.001	494.03410
Crude Fat (g/100g)	3.78±0.018[a]	3.78±0.016[a]	3.73±0.020[b]	3.83±0.023[c]	3.88±0.022[d]	3.81±0.026[e]	<0.001	50.63
Crude Fibre (g/100g)	1.43±0.12[a]	1.37±0.025[a]	1.56±0.68[a]	5.57±0.030[b]	5.61±0.022[b]	5.34±0.34[b]	<0.001	455.46
Carbohydrate(g/ 100g)	59.77±0.36[a]	60.063±0.054[a]	60.031±0.024[a]	78.080±0.019[b]	77.99±1.12[b]	78.12±0.016[b]	<0.001	3 809.23
Crude Protein(g/100g)	22.33±0.29[a]	22.12±0.068[b]	22.08±0.042[b]	7.61±0.020[c]	7.62±0.025[c]	7.61±0.022[c]	<0.001	38 191.88
Zinc (mg/100g)	0.62±0.082[a]	0.72±0.045[b]	0.60±0.014[a]	3.47±0.18[c]	3.77±0.021[d]	3.68±0.097[e]	<0.001	2835.77
Iron (mg/100g)	0.59±0.040[a]	0.71±0.051[b]	0.55±0.024[a]	8.40±0.17[c]	8.70±0.13[d]	8.69±0.15[d]	<0.001	13 586.71
Energy(kcal)	362.40±0.20[a]	362.76±0.34[b]	362.033±0.31[c]	377.25±0.29[d]	377.33±4.66[e]	377.24±0.20[f]	<0.001	162.45
Vitamin A mcg RAE	0.080±0.0087[a]	0.088±0.0031[a]	0.16±0.24[a]	0.13±0.0023[a]	0.11±0.0045[a]	0.11±0.0024[a]	0.532	0.83

**±SD- it simply means that, the sample result mean figure can deviate from the true value by ±SD observed value.*

Average element content with different superscript(s) along the row are statistically significant whilst those with the same or common superscript(s) are statistically insignificant for (p-value<0.05).

Generally, if the p-value is less than 0.05, the element content in Rapoko, Cowpea is statistically significant, and the F-values indicate which element is more significant than the other (the bigger the F-value the better).

Table 4.2: Nutritional content of RaCoB blends

Macro and Micronutrient content of RaCoB/ Dry matter basis (DMB) n=36					
Element	**Blended (85:15)**	**Blended (75:25)**	**Blended (60:40)**	**P-value**	**F-value**
Moisture (g/100g)	8.91±0.012[a]	7.32±0.021[b]	6.91±0.012[c]	<0.001	14349
Ash (g/100g)	3.32±0.020[a]	3.20±0.020[b]	3.03±0.058[c]	<0.001	45.13
Crude Fat (g/100g)	3.57±0.015[a]	3.46±0.015[b]	3.21±0.0058[c]	<0.001	637.27
Crude Fibre (g/100g)	2.42±0.021[a]	3.02±0.021[b]	2.60±0.015[b]	<0.001	780.12
Carbohydrate (g/100g)	59.30±0.015[a]	69.41±0.010[b]	61.43±0.067[c]	<0.001	53593.69
Crude Protein (g/100g)	22.39±0.010[a]	25.64±0.020[b]	22.82±0.015[c]	<0.001	38282.23
Zinc (mg/100g)	0.90±0.015[a]	1.74±0.015[b]	1.41±0.010[c]	<0.001	2841.41
Iron (mg/100g)	2.90±0.10[a]	5.14±0.012[b]	4.03±0.15[c]	<0.001	335.35
Energy (kcal)	358.93±0.095[a]	411.37±0.20[b]	365.86±0.30[c]	<0.001	54406.12
Vitamin A mcg RAE	0.084±0.0015[a]	0.11±0.0020[a]	0.092±0.0021[a]	<0.001	173.34

**The mean difference in elements is significant at the 0.05 level.*
**±SD- it simply means that, the sample result mean figure can deviate from the true value by ±SD observed value.*
**Average element content with different superscript(s) along the row are statistically significant whilst those with the same or common superscript(s) are statistically insignificant for (p-value<0.05).*
**Note: blend ratio (a: b)- means a% of Rapoko content as to b% content of Cowpea, for instance blend (85:15)- means 85% of Rapoko content as to 15% of Cowpea content.*
** Generally, if the p-value is less than 0.05, the element content in Blend Ratio is statistically significant and the F-values indicate which element is more significant than the other (the bigger the F-value the better).*

4.4 Discussion

Nutritional composition of Rapoko Cowpeas and Rapoko-Cow pea (RaCoB) blends

Moisture (g/100g)

Moisture is a very important factor to consider when buying rapoko and cowpea grains for blending because it affects shelf life of products and availability between seasons. Cowpea has the highest moisture content (9.11%) than rapoko which has (3,06%). Farmers should be capacitated to dry their produce to recommended safe moisture storage levels especially in high rainfall areas like Murewa. Farm produce that is stared at high moisture levels is most likely going to be affected by fungal disease. The results confirm recommendations from other studies that good post-harvest handling of produce is key to better shelf life for food products (UNDP.2018). Rapoko, cowpeas and RaCOB moisture levels are lower than a range of 7.8-13% which was reported in other studies (Asif et al. 2013). Rapoko and Cowpeas are normal stored at moisture below 12.5%. Lower moisture levels are highly recommended because they will allow small holders farmers to formulate blends and feed their children during lean seasons there by reducing malnutrition

Ash (g/100g)

There is more ash content in cowpeas (3.67%) than in rapoko (1.84%) and cowpeas from Murewa has more ash may be because of the soil amendment and agronomic practices given to the crop in that region. (Omoniyi, 2016). Rapoko grains are reported to have higher levels of minerals like calcium, potassium, and magnesium that are necessary in supporting nutrition (Asif et al. 2013). Ash content is key for the health of children and the content is within the range of 3.6-4.1% which was reported by (Asif et al. 2013). RaCoB blend ratio 85:15 has the highest ash (3.32%) with least in blend 60:40 at (3.03%).

Crude Fat (g/100g)

Rapoko has the highest crude fat content at (3.88%) with cowpeas having the least (3.73%) Fat contributes to fat acids for optimum neurological, immunological, and functional development in children below the age of 5 years. The results of this study concur with those done from other studies in terms of fat composition which ranges from 3.38-4.47% (Omoniyl, 2016). Blend ratio 75:25 has the highest crude fat at (3.46%) and blend ratio 60:40 having the least (3.21%). Higher crude fat levels in blend 75:25 may be attributed to mixing proportions. Crude fat in RaCoB blends is higher than the range of 1.2-3.4% that were reported by (Asif et al.

2013). Fats are important as they heighten the palatability of food, thereby increasing their intake children. Fat is statistically significant at P-value <0.001. Blending of cereals and pulses help increase fat composition.

Crude Fibre (g/100g)

This plays a crucial role as a broom in enhancing gastrointestinal movement and is statistically significant at p-value <0.001 in both cowpeas and rapoko. Rapoko has the highest crude fibre at (5.61%) than cowpeas (1.37%). Cereals have more fibre than pulses based on studies from ((Asif et al. 2013). Crude fibre content in RaCoB is relatively within the range of other studies at 2.6%-24% as reported by (Asif et al. 2013).This plays a crucial role as a broom in enhancing gastrointestinal movement and is statistically significant at p-value <0.001 in both cowpeas and rapoko. It has been observed that there is not much difference in Crude fibre content in rapoko and cowpeas may be because of the genotype of the two grains. The results of crude fibre from RaCoB are relatively within the range of other studies at 2.6%-24% as reported by (Asif et al. 2013).

Carbohydrate(g/100g)

This element is statistically significance in both Cowpeas and Rapoko at p-value <0.001.Carbohydrates levels in Rapoko (78.12%) are more than those in cowpeas (69.41%) thereby confirming results from other studies that cereals have more carbohydrates than pulses and blending the two will fortify the nutrient content and make available the required carbohydrates for children below the age of 5 years.

Crude Protein (g/100g)

The results confirm that Cowpea is a good source of protein than rapoko and this element is necessary for structural components of all body cells, tissue repair, cellular integrity, and other body functions for children below 5 years. The element is statistically significant at p -value <0.001 (ILechakwu,1996). Cowpeas from Murewa has the highest crude protein with Gokwe having the lowest because proteins may be easily denatured in hot regions. Crude protein in blend 75:25 falls within the range of (20.3%-27.7%) of other results as reported in (Asif et al. 2013). Crude Protein is important for structural components of all body cells. It plays a key role in cellular integrity, support body maintenance and growth,

Zinc (mg/100g)

There results depict that there is more Zinc in rapoko than cowpeas and blending the two will fortify the nutrient composition. Zinc is one of the missing link child development and is significant at P -value <0.001. Zinc levels in formulated blends is lower than other studies that ranged from 3.3-6.9% may because of the genotype of the varieties and agronomic practises given to the crops (Asif et al. 2013).

Iron (mg/100g)

There is more iron in Rapoko than cowpeas based on food groups. This is a major component of the red blood cell pigment and muscle. Iron is statistically significant at P-value <0. 001 and there is statistical significance difference in iron content across blends. When formulating blends, one should consider inclusion of rapoko which has (8.70.%) The levels of iron in blend ratio 75:25 (5.14%) falls with the range from other studies (5.3-15.9%) concurs with results from previous studies by (Asif et al. 2013).

Energy (kcal)

From the analysed results it is very clear that rapoko has high energy than since cereals are the prime source of energy in semi-arid tropics and drought prone regions of Africa and Asia. Inclusion of rapoko in these blends will provide the much-needed energy for the growth of children (Ravindhran, R, (2017). High Carbohydrates levels will combat protein -energy malnutrition in children below 5 years since there will be enough carbohydrates to provide energy and spare proteins for its primary functions.

Vitamin A mcg RAE

Rapoko and cowpeas do not have more vitamins since better amounts of vitamins are obtained from greens vegetables. Vitamin A is a serious threat to the wellbeing of children and pregnant women and needs to be available in all foods. It is pleasing to note that the selected blend (75:25) has more Vitamin A (0.11mcg RAE) than results from previous studies by (Asif et al. 2013).

Table 4.3: Proximate and mineral content of rapoko, cowpeas and RaCoB

Ingredients	Rapoko		RaCoB	
	Minimum	Maximum	Minimum	Maximum
Moisture (g/100g)	6.91±0.012^{c}	8.91±0.012^{a}	3.061±0.012^{c}	3.11±0.027^{c}
Ash(g/100g)	3.03±0.058^{c}	3.32±0.020^{a}	3.73±0.020^{b}	3.78±0.018^{c}
Crude Fat(g/100g)	3.21±0.0058^{c}	3.57±0.015^{a}	3.73±0.020^{b}	3.78±0.018^{c}
Carbohydrates(g/100g)	59.30±0.015^{a}	69.41±0.010^{b}	59.77±0.36^{a}	60.31±0.024^{a}
Crude protein(g/100g)	22.37±0.010^{a}	25.64±0.020^{b}	22.08±0.042^{b}	22.33±0.29^{c}
Zinc (mg/100g)	0.90±0.015^{a}	1.74±0.01^{b}	0.60±0.014^{a}	0.72±0.045^{b}
Iron (mg/100g)	2.90±0.10^{a}	5.14±0.012^{b}	0.55±0.024^{a}	071±0.051^{b}
Energy (kca)	358.93±0.095^{a}	411.37±0.20^{b}	322.03±0.31^{c}	362.76±0.34^{c}
Vitamin A (mcg RAE	0.084±0.015^{a}	0.11±0.0020^{a}	0.080±0.0087^{a}	0.16±0.24^{a}
Crude fibre (g/100g)	2.42±0.021^{a}	3.02±0.021^{b}	1.37±0.025^{a}	1.56±0.68^{a}

Results from characterization of rapoko were used as a control for blends. It is very clear that we have high carbohydrates, crude protein, zinc, iron, energy, vitamins, and crude fibre from the blends when compared to those in rapoko. This confirms the hypothesis of the study fortification of rapoko with produce highly nutritious blends necessary in addressing malnutrition.

4.5 Recommendations

It is important to ensure that rapoko and cowpeas are sourced from one location and the same variety is used so that the results are the consistent. The grains should be dried to recommended moisture levels to increase product shelf life. The element with the most significance is crude protein with a value of 38 191.88 and Vitamins with the least F-value of 0.83. Crude proteins in this regard are an important constituent of the diet and inclusion of a pulse (cowpeas) in this blend is key in the provision of proteins which are necessary for tissue repairs and addressing of malnutrition. Fortifying rapoko with cowpeas improves macro and micronutrients which are necessary in addressing malnutrition (energy, proteins, Zinc, and Iron) in children under the age of 5 years.

4.6 Conclusion

From the proximate analysis of rapoko, cowpeas and RaCoB blends it is crystal clear that we have more moisture in cowpeas particularly from high rainfall areas (Murewa). Farmers need to be capacitated on drying practises of different grain crop since this would affect product shelf life and availability between seasons. There is more proteins and ash in cowpeas and less carbohydrates, zinc, and iron. Rapoko has more zinc, Iron, and carbohydrates. Fortification of Rapoko with cowpeas produces a blend that has high nutritional value to be used as supplementary porridge for children under the age of 5 years. RaCoB blend 75:25 has the highest Proteins (25.64 ± 0.020^{b}) Zinc ($1.74\pm0.015^{b)}$, Iron (5.14 ± 0.012^{b}), Carbohydrates (69.41±0.010b), Energy (411.37 ± 0.20^{b}) and Vitamins (0.11 ± 0.0020^{a}) required by children under the age of 5 years. Blends with too high levels of cowpeas (60:40) and too low (85:15) have low levels of nutritional composition and acceptability may be due to antinutritional factors.

4.7 References

1. United Nations Development Program Report, 2018.
2. Omoniyl A, A. A., 2016. A Proximate analysis and mineral compositions of different cereals available in Gwagwalada market, F.C.T, Abuja. Journal of advances in food science and Technology.
3. Asif M.L. W. Rooney. Ali and M.N Riaz ,2013.''Application and opportunities of pulses in food system: Review'', Critical Reviewers in Food science and Nutrition.
4. ILechakwu, E.N. (1996). Cowpeas production.
5. Ravindhran, R, 2017. Biofortification in Millets: A sustainable approach for Nutritional security.
6. Garrow, J. S. et al., 1999. Human Nutrition and dietetics,10th ed. London, Churchill, Livingstone.

CHAPTER 5: RESULTS Sensory acceptability evaluation of Rapoko-Cow pea (RacoB) developed porridge blend

Abstract

Sensory evaluation was done for all the three blends with the view of determining acceptability levels of the different blend ratios (85:15,75: 25 and 60:40 formulated in this study. Sensory evaluation and overall acceptability were done with 100 panellists (70 untrained and 30 trained). RaCoB blend 75:25 was overall accepted with a value of 13.69 ± 1.034^{b} and blend ratio 60:40 being the least. It had the highest score for all sensory attributes. Colour and Appearance (4.69 ± 0.47^{b}) Taste and Aroma (4.53 ± 0.59^{b}), Body and Texture (4.47 ± 0.50^{b}). Nutrition information of a product is an important factor that determines purchase of a new product and RaCoB is highly nutritious to be purchased by consumers (Muzhingi et al 2008).No Rapoko control was used during sensory evaluation since the objective was to formulate and test blends.

5.1 Introduction: This chapter covers sensory evaluation for all the three blends with the view of determining the acceptability of different blend ratios (85:15,75: 25, 60:40) and pick the best blend to support nutrition of children below the age of 5 years. Overall Acceptability: refers to the general acceptance of the product with reference to all the discriminating sensory attributes of the sample. Sensory evaluation and overall acceptability were done with 100 panellists (70 untrained and 30 trained after signing consent forms and other ethical considerations.

5.2 Material and Methods: Refer to Chapter 3

5.2.1 Description of study area: Qualitative evaluation was done for all blends using the following sensory attributes on 5-point hedonic scale; (Colour and Appearance, Taste and Aroma, Body and Texture).

5.2.2 Research Design: A cross sectional survey with 100 panelists (70 untrained: 30 trained) through a qualitative sensory questionnaire was used.

5.2.3 Sampling procedure: A total of 100 (30 trained and 70 untrained) volunteer panelists drawn from the Food science department helped in the evaluation of the RaCoB blends. The purpose of the evaluation was explained to them as well as the significance of the study. Volunteer panelist were asked to sign consent and indemnity forms.

5.2.4 Data collection procedure: Data from sensory evaluation was electronically captured and analysed in SPSS.

5.2.5. Data from sensory evaluation was analysed using non-parametric tests since the data could not meet the assumptions of parametric ANOVA. Hence Kruskall-Wallis test was used, and mean separation was done using LSD at 5 % significance level for nutritional composition and acceptability of Rapoko, Cowpeas and RacoB using Statistical significance $p<0.05$ were done and generated data was presented using graphs and tables

5.2.6 Challenges encountered during data collection: Fear of contracting COVID 19 via questionnaires.

5.2 Results

Table 5.1: Sensory evaluation result

**The mean difference in elements is significant at the 0.05 level, meaning to say there is difference in element composition by blend*

Research Question 3**: Determine the acceptability of different RaCoB blends through sensory evaluation attributes (Texture, Colour, Aroma, and overall acceptability).**

Samples	**Colour and Appearance**	**Taste and Aroma**	**Body and Texture**	**Overall Acceptability**
Blended (85:15)	3.76±0.74[a]	3.90±0.59[a]	4.18±0.86[a]	11.84±1.71[a]
Blended (75:25)	4.69±0.47[b]	4.53±0.59[b]	4.47±0.50[b]	13.69±1.034[b]
Blended (60:40)	3.02±0.97[c]	3.18±0.97[c]	2.77±0.91[c]	8.97±2.23[c]
P-value	<0.001	<0.001	<0.001	<0.001
F-value	77.43	52.21	83.6	117.92

**±SD- it simply means that, the sample result mean figure can deviate from the true value by ±SD observed value.*

**Average attributes mark with different superscript(s) along the column are statistically significant whilst those with the same or common superscript(s) are statistically insignificant for (p-value<0.05)*

**Note: Only females were considered in the above analysis*

**Note: blend ratio (a:b)- means a% of Rapoko content as to b% content of Cowpea, for instance blend (85:15)- means 85% of Rapoko content as to 15% of Cowpea content.*

** Generally, if the p-value is less than 0.05, the attribute in the Blend Ratio is statistically significant*

and the F-values indicate which attribute is more significant than the other (the bigger the F-value the better)

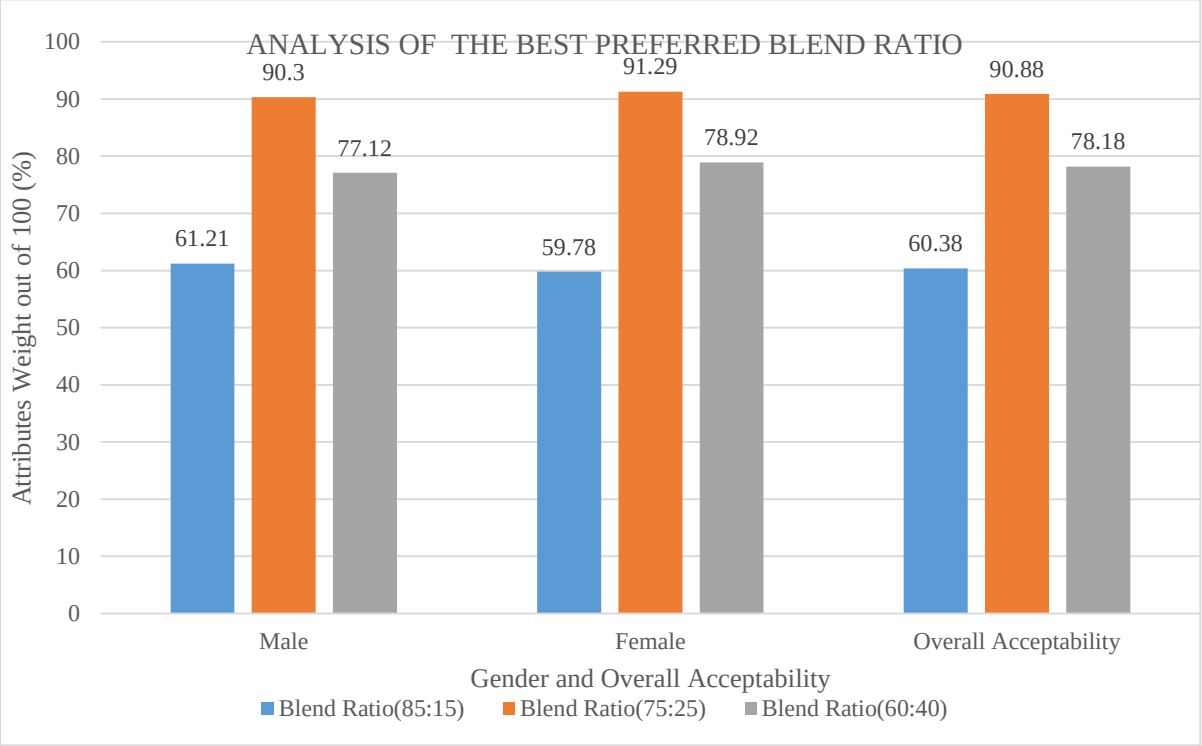


Figure 5.1: Sensory evaluation blend ratio by gender

** Male consumers, preferred blend ratio (75:25) with 90.30% weightage, followed by blend ratio (60:40) with 77.12% weightage and lastly by the blend ratio (85:15) with 61.21% weightage. Female consumers preferred, blend ratio (75:25) with 91.29% weightage, followed by blend ratio (60:40) with 78.92% weightage and lastly by the blend ratio (85:15) with 59.78% weightage.*

5.4 Discussion

Colour and Appearance

This is an important in food choice and acceptance. There is statistical significance difference in acceptability of blends based on colour and appearance of blends. Different blends produce different colours and appearances because of the proportion of ingredients in the blend. This is a very important factor for panelists because we eat first with our eyes. RaCoB blend 75:25 has the most appealing colour and appearance and acceptability by panelists. Increasing or decreasing blending ratios influences the colour and appearance of the porridge.

Taste and Aroma

Different blends produce different tastes which are influenced by mixing ratios. Pleasant taste helps people to make decisions around freshness of food and this is perceived from a combination of attributes like, touch, mouthfeel, sight, and hearing. Food may be appealing but if the taste is not good then its acceptability may be low, and it has a high mark in this study. Taste was noted as the most significant factor in sensory evaluation and rejection of a food product during sensory evaluation is due to bitter taste and rough texture (Catherine, 2019). In this study addition of salt and sugar in the porridge enhanced the taste and is also a common practise by most women in Zimbabwe when feeding their children with supplementary foods. Women had better acceptability score than men because previous studies have confirmed that women have more olfactory bulb giving them a better odour memory than men and have more superiority in the identification of bitterness, sour, sweetness because of they have better stereognosis than men (Lawless, H.T,2013).

Body and Texture

The results confirm findings from other studies that indicated that body and texture are key in determination of food acceptability. (Kemp et al,2009). There is statistically significant difference in body and texture of different RaCoB blends because of the thickness and texture of the porridge. Too thin or too thick porridge may have low acceptability

Overall Acceptability

The results of this study have also confirmed that women are considered key players in the overall acceptability of the blends because they play a key role in health care and upkeep of children (Lawless, H.T,2013). In Zimbabwe we have more women than men (52% men and 48 % men) Zimbabwe Census,2012). The participation of women in food formulation and sensory evaluation will encourage them to gain nutrition knowledge and positive attitudes towards the importance of dietary improvements in children below the age of 5 years, A study from the institute of food science Technology indicates that more men are colour blind and experience hearing losses as they age unlike women who are good in discriminating colours and are superstars in bitter identification (Oliveira-Pinto A, 014).The objective of this study was to develop highly nutritious blends and subject them to sensory evaluation using blending ratio from other studies (Ch, M. (2013).

5.5 Recommendations

When conducting sensory evaluation, it is important to involve more women than men as panelist because of their superiority in sensory attributes especially taste, Aroma, and colour. The use of students and young mothers in sensory evaluation may not give a true preference and acceptability of blends because of the limited reliability of the answers. Measuring food intake by children can be done but the method is very expensive as it requires numerous consumption surveys.

5.6 Conclusion

Form the results of sensory evaluation blend ratio (75:25) was the most preferred with a van F-value of 13.69. Women scored the blend a score of 91.29% and men 90.3% on weightage. Nutritional information is the most important factor that determines purchase of nutritious food and RaCOB is highly nutritious to address malnutrition in children under the age of 5 years and may have better acceptability on the market (Muzhingi, et al 2008).

5.7 Reference

1. Muzhingi, T., A. Langyintuo, L. Malaba, and M. Banzinger. 2008. Consumer acceptability of yellow maize products in Zimbabwe. Food Policy 33: 352–361.
2. Lawless (2013). Laboratory exercise for Sensory Evaluation. Springer, New York.
3. Kemp et al. 2009. Sensory Evaluation. A practical Handbook, s. l. s. n.
4. Zimbabwe Population Census 2012, Report.
5. Oliveira-Pinto A. V., et. al. 2014. Sexual Dimorphism in the Human Olfactory Bulb: Females Have More Neurons and Glial Cells than Males. PLOS One, Volume 9/
6. Ch, M. 2013. Utilization of common grain crops in Zimbabwe. African Journal of Food Science, 7(9), 253–257. https://doi.org/10.5897/ajfs2013.1011
7. Catherine N, Kunyanga, George O, Abeng, John O, Ojiem and James N, Muthomi, 2019. Accessing sensory characters and consumer preference of legume-cereal-root based porridges in Nandi Country.

CHAPTER 6: SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

6.1 Introduction

This chapter presents a summary of the Research findings, conclusion, and policy implications on recommendations. It also provides areas for further studies.

6.2 Research summary

Rapoko and Cowpeas from different locations have high levels of macro and micronutrients (Vitamin A, Iron, Zinc, crude protein, crude Fat, Total ash, fibre, Energy, moisture content and carbohydrates). This study has managed to characterize the proximate analysis and realised that the two grains have macro and micro element levels which are necessary in addressing malnutrition in the face of COVID 19 global pandemic. What is also coming out in this study is that fortification of Rapoko with Cowpea makes available sufficient quantities of key elements like Zinc, Iron, Vitamin A and Proteins which play a key role in addressing daily nutrients intake by children below the age of 5 years. Most importantly is to note that different blends have different acceptability levels based on standard sensory attributes (Texture, Colour, Aroma by gender). Women play an important role in sensory evaluation because of their superiority in differentiating colours and taste and aroma

6.3 Conclusions

Major findings from the study are Rapoko and Cowpeas are nutritious grains with high macro and micronutrients content necessary in supporting optimal health, growth, and development in children under the age of 5 years. The nutrient composition is in the range of WHO recommended daily macro and micronutrient intake by children under. 5 years (Garrow et al,1999), Blending of Rapoko and Cowpeas undoubtedly fortifies the levels of macro and micronutrients which are required in addressing malnutrition in both developed and developing countries. Attention should be paid to the blending ratios which have a bearing on nutrient composition of the developed new product. Overall acceptability of different blends is greatly influenced by sensory factors like taste and aroma, colour and appearance, and body and texture. Body and texture are the most important attributes at with 83.6 and Taste and Aroma being the least at 52.21. Women were considered key players in the overall acceptability of the blends because we have more women in sensory panels and evaluations and women are key in health care and upkeep of children. All the study hypothesis was met since rapoko, cowpeas and RaCoB blends proved to have high nutrient levels necessary to support nutrition in children below 5 years. From sensory results it is also clear that different RaCoB blends have different acceptability levels based on sensory factors and results from panelists.

6.4 Policy implication and recommendations

The government must be encouraged to invest in nutrition, address inequalities in the food system, make sustainable health foods accessible and affordable by all the people to address malnutrition. Integration of nutrition in health systems and strong stakeholder coordination and nutrition education is key in addressing malnutrition. Inequalities in food and health systems exacerbate inequalities in nutrition thereby making undernourished children have weaker immune systems and may be at greater risk to COVID 19 pandemic.

The results of this study are important in informing policy makers on the importance of fortifying Rapoko and Cowpeas in addressing malnutrition and positively influence its adoption. Policy makers should give priority towards supporting production of Rapoko and Cowpeas by small holder farmers to increase the availability of the two grains for low cost biofortification by urban and poor households. This may be done in three folds; through provision of improved seeds through government support schemes, Intensification of extension in line with best agronomic practises of the two crops.

Capacity strengthening of Research and development in breeding high yielding varieties and support other value chain actors for better processing and value addition. The government may also consider reviewing Rapoko and Cowpea producer prizes to enhance demand driven production. Further support may be required in commercialization of RaCoB.

6.5 Areas for further research

The research recommends further detailed studies on the nutritional gains by children who are fed on RaCoB. A detailed study on anti-nutritional inhibitors like protease, lipase, phytic, oxalic acids and oxalates) that may affect intake of the porridge must be done. Furthermore, it is important to have an in-depth study of the shelf life of the developed new product and lastly understand bio availability of the grains used in this study.

6.6 References

1. Ch, M. 2013. Utilization of common grain crops in Zimbabwe. African Journal of Food Science, 7(9), 253–257. https://doi.org/10.5897/ajfs2013.1011

2. Serere Harusekwi Julien, B.B., 2016. Development of Fermented Corn and Rapoko Blend Instant Porridge. International Journal of Nutrition and Food Sciences, 5(4), 246.https://doi.org/10.11648/j.ijnfs.20160504.13

3. Mukarumbwa, P., & Mushunje b, a. 2010. Potential of Sorghum and Finger Millet to enhance Household Food security in Zimbabwe's semi-arid regions, s.i.sn

4.UNICEF, 2019. Children. Annual Report, For Every Child Reimagine, s. i. s. n

5.Wessells, K. R., Singh, G., & Brown, K. 2012. Estimating the Global Prevalence of Inadequate Zinc Intake from National Food Balance Sheets: Effects of Methodological Assumptions. PLoS ONE. https://doi.org/10.1371/journal.pone.0050565.t003

6. ZimVAC. 2019. Zimbabwe Vulnerability Assessment Committee. Retrieved from www.fnc.org.zw. info@fnc.org.zw

7. Omoniyl A, A. A., 2016. A Proximate analysis and mineral compositions of different cereals available in Gwagwalada market, F.C.T, Abuja. Journal of advances in food science and Technology.

8. Ashwani, K., 2018, Millets: A solution to agrarian and nutritional challenges. Research Gate

12. ILechakwu, E.N. (1996). Cowpeas production.

19. AOAC, 2000 Official Methods of Analysis. 17th Edition, The Association of Official Analytical Chemists, Gaithersburg, MD, USA. Methods 925.10, 65.17, 974.24, 992.16.

20. Sahel, Ahmed S.M Qing Zhang, Jing Chen, and Qun Shen 2013. "Millets Grains; Nutritional Quality. Processing, and potential Health Benefits; Millet grains'', Comprehensive Review in Food Science and Food safety.

21. Onyango, C. 2004." Proximate Global composition and digestibility of fermented and extruded uji from maize-finder millet blend'' LWT food Science and Technology.

22. Astuti Verma, 2019. Physico-Chemical properties and nutritional composition of improved varieties of grain cowpeas grown in pantnagar.

24. Garrow, J. S. et al., 1999. Human Nutrition and dietetics,10th ed. London, Churchill, Livingstone.

24. Lawless (2013). Laboratory exercise for Sensory Evaluation. Springer, New York.

25. Oliveira-Pinto A. V., et. al. 2014. Sexual Dimorphism in the Human Olfactory Bulb: Females Have More Neurons and Glial Cells than Males. PLOS One, Volume 9, Issue 11.

26. Moyo, S., 2000. Zimbabwean environmental dilemma: balancing resource inequalities. Harare, Zimbabwe Research organization.

27. Polit, D. F., & H, B. P. 1999. Nursing research: Principles and methods. Philadelphia: JB Lippincott Company.

31. Zimbabwe Population Census 2012, Report.

32. Food and Agriculture Organization of the United Nations, 2011, FAO book production Rome, Italy.

33. Asif M.L. W. Rooney. Ali and M.N Riaz ,2013.''Application and opportunities of pulses in food system: Review'', Critical Reviewers in Food science and Nutrition.

34. Nyankori, J. 2002. Product life cycle model of Cowpeas based products in Ghana. Department of agricultural and applied economics. Chemson University, Clemson, SC. USA.

35. Ravindhran, R, 2017. Biofortification in Millets: A sustainable approach for Nutritional security.

36. Awuchi, Chinaza Godswill 2019. Proximate composition and functional properties of different grain flour composites for industrial applications.

37. Devi P, V. R. 2014. Health benefits of Finger millet (Eleusine Coracana L. Polyphenols and dietary Fabre. Improving Feeding Practices: Current Patterns, Common Constraints, and the Design of Interventions. Food Nutrition. Bull., 24: 24-82.38. Pelto G.H, Levitt E, Thairu L

38. Afshin, A., 2020.Global Nutrition Report, 2020.

39. Pelto G.H, Levitt E, Thairu L, 2003. Improving Feeding Practices: Current Patterns, Common Constraints, and the Design of Interventions. Food Nutr. Bull., 24: 24-82.

40. Kemp et al. 2009. Sensory Evaluation. A practical Handbook, s. l. s. n.

41. Fredrick, M, J., 2015. Assessing and addressing global nutrition. Jama 313 (3) 232.

43. Becker, G, 1981. A Treatise on family. Cambridge, Mass; Harvard University Press.

44. Beddington, 2011. Achieving food security in the face of climate change: summary for policy.

45. Muzhingi, T., A. Langyintuo, L. Malaba, and M. Banzinger. 2008. Consumer acceptability of yellow maize products in Zimbabwe. Food Policy 33: 352–361.

46. World Food Programme, 2006. Micronutrient fortification: WFP experiences and ways forward. Food and Nutrition Bulletin 27: 67-75.

47. Talsma E.F, Brouwer ID, Verhoef H, Mbera GN, Mwangi AM, Demir AY, Maziya-Dixon B, et al 2017. Biofortified yellow cassava and vitamin A status of Kenyan children: a randomized controlled trial. American Journal of Clinical Nutrition.

48. United Nations Development Program Report, 2018

Appendices

Appendix

Appendix A: Household questionnaire

Name of Evaluator……... Gender……

Introduction

Considering growing concerns over the persistent malnutrition faced by children under the age of 5 years, this study developed a Rapoko and Cowpea blend (RacoB) to address this challenge. This questionnaire seeks to evaluate the new product which was constituted using different ratios.

Directions.

Please tick (√) in the respective Sensory Scale Factors for each of the Sensory Quality Factors Each Sensory Quality factor is awarded marks as follows: Liked extremely (5 marks), Liked moderately (4 marks), Neither liked nor disliked (3 marks), Disliked moderately (2 marks) Disliked Extremely (1 mark).

After evaluating the samples, please give weightage for each of the quality attributes out of 100.

Sensory Quality Factors	Sample Number	Scoring scale factors					
		Liked extremely (5marks)	Liked moderately (4 marks)	Neither liked nor disliked (3 marks)	Disliked moderately (2 marks)	Disliked Extremely (1 mark)	Relative weightage of Factors out of 100
Colour and Appearance	S1						
	S2						
	S3						
Taste/Aroma	S1						
	S2						
	S3						
Body and Texture	S1						
	S2						
	S3						
Comments:							

Appendix B

Figure 1