VALUE ADDITION AND FORTIFICATION OF NATIVE CEREALS, LEGUME CROPS AMONG SMALLHOLDER FARMERS IN SEMI-ARID AREAS OF ZIMBABWE

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

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The undersigned certified that they have supervised and recommended to Bindura University of Science Education for acceptance of dissertation entitled '**VALUE ADDITION AND FORTIFICATION OF NATIVE CEREALS AND LEGUME CROPS AMONG SMALLHOLDER FARMERS IN SEMI-ARID AREAS OF ZIMBABWE'** submitted in partial fulfillment of a Master of Science Degree in Food Security and Sustainable Agriculture.

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DECLARATION

I hereby declare that the research project entitled "**VALUE ADDITION AND FORTIFICATION OF NATIVE CEREALS AND LEGUME CROPS AMONG SMALLHOLDER FARMERS IN SEMI-ARID AREAS OF ZIMBABWE**" 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 (BUSE) and Dr E Nyakudya (UZ) and this work is submitted in partial fulfilment of the requirements for the award of a Master of Science Degree in Food Security and Sustainable Agriculture. The results embodied in this thesis have not been submitted to any University or Institute for the award of any degree of diploma.

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DEDICATION

I dedicate this thesis to my mother Mrs Marongwe, my wife Caroline, and my entire family members. I forever thank you for the support you gave me and will always be grateful. Above all, I give thanks to the almighty God for making this journey possible. Without God, it could have been difficult to reach this far, his strength continues to raise me up.

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ABSTRACT

Value addition and fortification of native cereal based foods with essential micronutrients has been proved to be an effective way of reducing deficiencies in micronutrients at household level and especially in rural communities. Strategies for national fortification usually do not make significant differences in the remotest areas which are not reached by commercially produced foods. The feasibility and sustainability of small scale value addition and fortification as a mechanism to overcome this barrier are not well documented. The main objective of this study was to develop sesame fortified sorghum and pearl millet porridge. A Completely Randomised experimental Design (CRD) was conducted to develop six different formulation combinations of sesame, sorghum and pearl millet. Raw materials used in the formulation of the porridge blends were subjected to proximate analysis to determine the overall macro and micro nutrient composition. The raw materials were roasted at 70 degrees Celsius at varying roasting times of 10 min and 20 minutes in an oven. Combinations of cereal – legume mixtures were mixed in the laboratory to produce six fortified porridge blends which were also analysed for their nutrient content. The porridge blends were also subjected to sensory evaluation to determine the acceptability of the porridge blends to semi trained panellist. Results show that there significant differences ($p<0.05$) in both macro and micro nutrients between the different formulation combinations of the porridge blends. Cereals had the highest amounts of carbohydrates, while the legumes had high fat and protein content. Significant differences ($p<0.05$) were also noted on micro nutrients in the raw materials with potassium, calcium and iron topping in micronutrient content. Nutrient analysis of the porridge blends showed significant ($p<0.05$) variation in amount of protein, fat, moisture and ash. Potassium and calcium were found to be lower than the recommended daily allowance acceptable in diets of 500mg and 400mg while iron and zinc were within the recommended daily allowance of 6.0mg and 5.0mg. Sensory evaluation done on all the porridge blends using the Kruskal-Wallis H test showed that there were statistically significant differences in taste, flavour, appearance and texture between the different porridge formulations. X^2 (6) = 86.271, p = 0.001 for appearance, χ^2 (6) = 146.86, p = 0.001 for taste, $\chi2$ (6) = 221.06, p = 0.001 for flavour, and χ^2 (6) = 101.76, p = 0.001 for texture. The highest mean rank for taste was noted on Blend 3 followed by B6 with the least in terms of appearance being the control. Flavour had similar results like taste and appearance while B5 scored highest on texture. Blend B3 (60g Sorghum + 20g Pearl millet + 5g Groundnut + 15g Sesame) which was scoring high on taste, flavour and appearance would be a favourable combination for consumers. A post Hoc test using LSD for the mean scores between the formulations revealed that for appearance blend B2, B4 and the control were significantly different ($p<0.05$) from the other blend. For taste, B2 was significantly different ($p<0.05$) than all other blends. Blend B2, B4, B5 and B6 were significantly different ($p<0.05$) in flavour from the rest of the other blends. B2, B3 and B4 were significantly different ($p<0.05$) from the rest of the blends on texture. Results show that legumes have higher quantities of macro and micro nutrients compared to cereals and that there was significant contribution of micronutrients from sesame. Sesame can therefore be recommended to be in cooperated in formulation of complementary diets for resource poor small holder farmers.

Keywords: Cereals; Fortification; Sensory evaluation; Micro nutrients; Sesame; Legumes.

LIST OF ACRONYMS AND ABBREVIATIONS

1. ANOVA – Analysis Of Variance
2. AOAC – Association Of Analytical Chemist
3. ATP – Adenosine Triphosphate
4. DNA – Deoxyribose Nucleic Acid
5. FAO – Food and Agricultural Organisation
6. Fe – Iron
7. FPS – Fixed Point Scales
8. HIV – Human Immune Virus
9. IDA – Iron Deficiency Anaemia
10. K – Potassium
11. Mn – Manganese
12. MoHCC – Ministry of Health and Child Care
13. NGO – Non Governmental Organisation
14. PEM – Protein Energy Malnutrition
15. SADC – Southern African Development Community
16. SAT – Semi Arid Tropics
17. SPSS – Statistical Package for Social Sciences
18. SRM – Standard Reference Material
19. UKAID – Department for International Development
20. UNICEF – United Nations Children's Educational Fund
21. VAD – Vitamin Deficiency Anaemia
22. VAS – Visual Analogue Scales
23. WFP – World Food Program
24. WHO – World Health Organisation
25. ZIMSTATS – Zimbabwe National Statistics Agency
26. Zn – Zinc

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CHAPTER 1
INTRODUCTION

1.1 Background of the study

Micro nutrient malnutrition caused by inadequate intake of nutrients is one of the major nutritional problems in Africa (Omoba, Taylor, & de Kock, 2015). Deficiencies in micro nutrients such as iron, zinc vitamin A rank highest among leading causes of death in developing countries (WFP, 2006). In developing countries like Zimbabwe, micronutrient malnutrition is a cause of concern. Effects of such mineral deficiencies are common in children mainly because they are weaned abruptly into starchy foods that are bulky and sometimes lack important macro and micro nutrient (Charles, 2017). Formulation and development of nutritious complementary foods from local and readily available raw materials has received considerable attention in many developing countries. According to Gadaga et al., (2009), 65% of Zimbabwean population live in rural areas and these people are food insecure as a result of droughts. This population experiences fluctuating levels of malnutrition due to micronutrient deficiency. Mukarumbwa & Mushunje, (2010) concluded that, productivity of small grains and legume crops competes with maize crop which is a staple crop in natural regions IV and V despite the areas being too dry for successful cropping. Besides the added advantage in production small grains for farmers in natural region IV and V, yield of these crops fall way below national avarages (0.3t/ha) (SICNA/ICRISAT, 1998) because communal farmers use low yielding varieties as well as insufficient government support to promote small grai production (Mukarumbwa & Mushunjeb, 2010). Small grains contribute significantly to household food security especially among smallholder farmers as a major source of energy, protein for over one billion people in the semi-arid tropics (Rohrbach & Mutiro, 1997). However, sorghum, millets and some legume crops like sesame (*Sesamum indicum*) still lack research compared to other crops like cereals and this results in underutilisation of the crop by farmers. Low productivity of small grains and edible legumes causes unattractiveness of these crops to communal farmers, yet they are rich and important sources of macro and micronutrients. Common food products produced from these cereal crops are *sadza,* porridge and traditional beer while *maheu* is a common non-alcoholic beverage (Dera, 2017). Most complementary foods in smallholder farmer set ups are usually cereals that are processed into unblended porridges. Besides the bulkiness, these porridges are of poor nutritional value (Solomon, 2005). Traditional weaning foods used by smallholder communities can be improved by incorporating locally available protein rich materials such as ground nuts and sesame. While commercial formulas are considered nutritious, acceptable and safe, the high cost puts them beyond the reach of many smallholder farmers and especially those in low income bracket (Solomon, 2005). Families in the smallholder set up rely on locally formulated diets to feed infant and young children, however, the porridges formulated are low in protein while the levels of anti-nutritional factors reduces bioavailability of important minerals (Solomon, 2005). In addition, essential micronutrients that are critical in addressing micronutrient malnutrition are sometimes lost to the extent of 50-90% during processing (Rosell, 2015), hence the need for value addition and fortification of these crops. The high rates of malnutrition across developing countries has prompted researchers to look into ways of processing locally available foods in the view of improving their nutritive value as well as introduce variety in diets. Zimbabwe's malnutrition rates stand at: stunting – 26.2%, underweight – 8.8%, wasting – 2.5% (Zimbabwe National Nutrition Survey, 2018) with the majority of cases are in the rural areas. This study was carried out with focus on Buhera South and Mount Darwin districts of Zimbabwe located in natural regions IV and V where of prevalence of malnutrition in the districts stands at (Buhera South: stunting 26.3%, underweight 7.3% and wasting 2%, Mt Darwin: stunting 27%, underweight 11.8%, wasting 4%) respectively according to the Zimbabwe National Nutrition Survey, (2018). The figures though not very far from the national average, are still high and efforts to reduce the prevalence of malnutrition are therefore needed in the view of reaching the objectives of micronutrient food security. Sesame *(Sesamum indicum)* is one underutilised crop grown by smallholder farmers with huge potential to address effects of malnutrition. Similar to legume crops, sesame is rich in protein, dietary fibre, folate, calcium, manganese, magnesium, vitamin B1 and iron (Bamigboye et al., 2010) and thus maybe used to complement the dominant starchy diets of the rural poor. Sesame can stand as cheaper source of micronutrients due to its superiority in micronutrient availability in the seed. Not much works has been done in developing range of products from cereals and sesame and how these products affects consumer preferences compared to the traditional products. This study therefore focused on value addition and fortification of small cereal grains using legume crops and sesame through development of a fortified porridge aimed improving micronutrient malnutrition among smallholder farmers residing in marginalised areas.

1.2 Problem statement

Commercially produced conventional food supplements in Zimbabwe are expensive and cannot be afforded by many citizens, while at the same time locally produced complementary foods are mainly starchy leading to lack of supply of required micronutrients hence high rates of malnutrition for children who are the most vulnerable. Sorghum, pearl millet, groundnuts and sesame are crops grown in the semi-arid regions of Zimbabwe and regarded as cheap and readily available sources of food for many smallholder farmers (Rohrbach & Mutiro, 1997). Despite small grains being highly nutritious, most rural communities are unaware of the potential of these crops in addressing malnutrition and hence lack essential micronutrients that are critical in addressing micronutrient malnutrition among vulnerable groups. Micro nutrient deficiencies across all age groups in Zimbabwe is on the rise according to MoHCC, (2014). Deficiencies in Vitamin A affects 19% of under-fives, 25% of children living with HIV, 23% of women 15-49 years and 27% of rural woman, while iron deficiency in children in rural areas stands at 37% and 27% for women (ZIMSTAT and ICF International, 2012). According to the Zimbabwe National Nutrition Survey, (2018), Buhera South's stunting rate stands at 26.3%, underweight - 7.3% and a wasting - 2%, while Mt Darwin stands at: stunting – 27%, underweight – 11.8%, wasting – 4%. These figures are a cause of concern especially for Mt Darwin district which is above the national average. (Stunting–26.2%, underweight – 8.8%, wasting – 2.5%). These districts have not been spared from the effects of malnutrition. Sesame is one crop rich in essential macro and micro nutrients and is grown in these districts. However, small grains and legume crops are underutilized yet people in these communities continue to suffer from malnutrition. There is potential for people in these communities to fully utilize these crops through value addition and fortification of these crops and also address problems of malnutrition by promoting growth and utilisation of the crops and their products. The main objective of this study was therefore: to formulate and develop a fortified porridge made from sorghum pearl millet, groundnuts and sesame, determine the proximate, mineral content and sensory attributes of the developed product.

1.3 Objectives of the study

1.3.1 Main objective

- To formulate, develop and evaluate sensory attributes of a fortified porridge product using sorghum, pearl millet, groundnut, and sesame from semi-arid regions of Zimbabwe.

1.3.2 Specific objectives are to:

1. Determine the nutrient composition of raw materials (sorghum, pearl millet, groundnuts and sesame) as well as formulated fortified porridge.
2. Develop fortified porridges from the different formulations (combinations) of sorghum, pearl millet, groundnuts and sesame.
3. Evaluate sensory properties of fortified porridges developed from sorghum, pearl millet, groundnuts and sesame.

1.4 Research hypothesis

1. Legumes such as sesame and groundnuts have high content of proteins, fats and micronutrients as compared to cereals (pearl millet and sorghum).
2. The nutritional composition of the formulated porridge blend products are rich in micro nutrients (potassium, magnesium and iron) compared to raw cereal and legume grains.
3. Consumer sensory properties evaluation of the different porridge blends formulations shows that they have favourable taste, flavour, appearance and texture relative to isolated consumption of cereals.

1.5 Justification

Attempts to find workable solutions to addressing the problem of malnutrition should take into account locally grown and known resources such as the use of sorghum, pearl millet, groundnuts and sesame grown by smallholder farmers. The study sought to develop knowledge that could be used by smallholder farmers on alternative crops that are cheap, readily available which can be used to address micro nutrient malnutrition. The study also contributes to communities to come up with value added products that can address food and nutrition issues and ultimately improve their livelihoods in the form of income, employment, health and education. Information generated from this study can also be used by other stakeholders such as the Ministry of Health and Child Care, Ministry of Agriculture, Water and Climate, NGO, rural communities and the academic fraternity. Further research can also be triggered by this research to provide improvements or develop different value added products for improved nutrition.

1.6 Scope/delimitations and limitations of study

1. Analysis for anti-nutritional factors and shelf life was not done due to time constrains
2. Use of limited equipment and alternative chemicals in the proximate analysis for example use of a uncontrolled oven for roasting, and use of petroleum ether instead of hexane during oil extraction.

1.7 Outline of Thesis

This thesis contains six chapters. The first chapter displays the overview of the study. Following the introductory chapter is chapter two devoted to relevant literature. Presentation of research methodology is chapter three while the fourth and fifth chapter displays the main findings of the research. Chapter six summarizes and concludes the findings and reflects some recommendations and policy implications of the study.

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CHAPTER 2
LITERATURE REVIEW

2.1 Introduction

This chapter presents a systematic review of relevant literature regarding productivity and utilisation of cereals and legume crops in Zimbabwe. The chapter starts by an analysis of the conceptual framework which underpins this research and depicts factors contributing to individual nutrition status and further describes the micronutrient analysis of sesame and its significance to human nutrition. The chapter also describes the utilisation of cereal and legume crops including sesame in Zimbabwe and the potential that the crops has in micronutrient supplementation.

2.2 Conceptual/theoretical framework

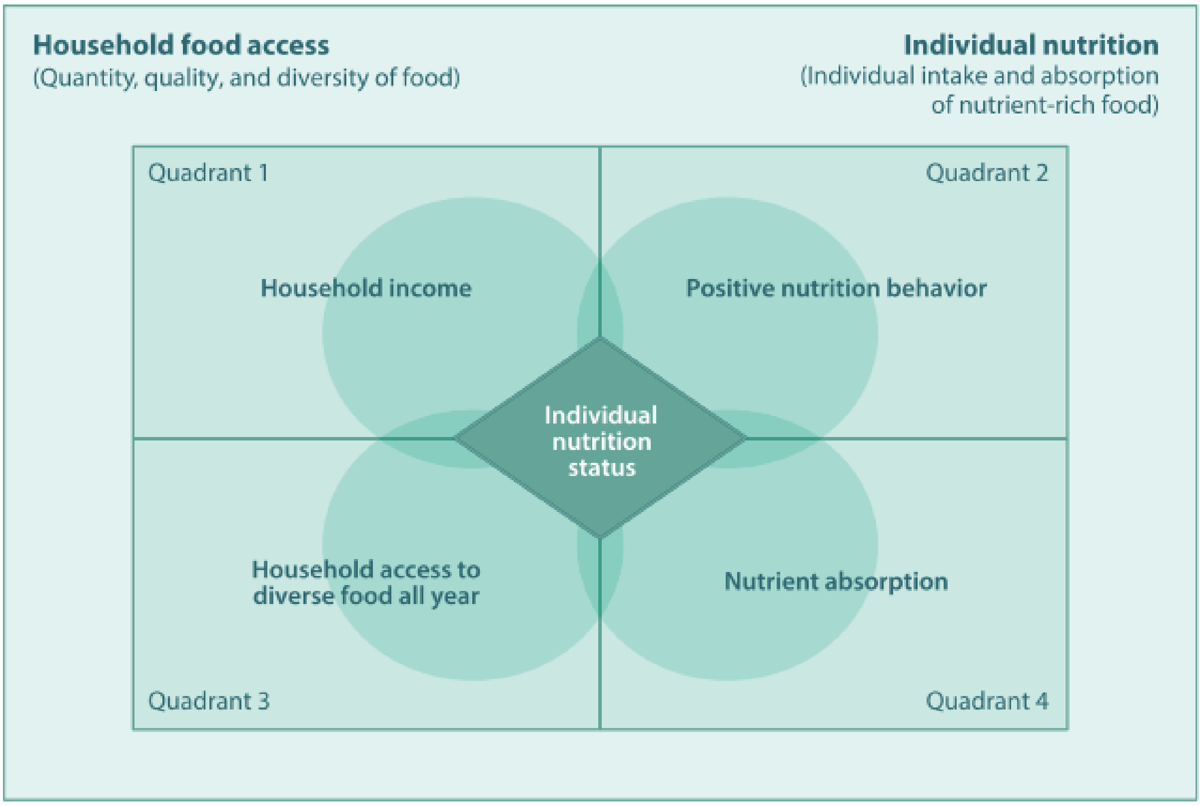

Figure 2.1 Multisectoral pathways towards improved individual nutrition. Adapted from (Pingali & Sunder, 2017).

This multidimensional frame work for explaining the driver of nutrition change is explained in terms of the four quadrants, Pingali and Sunder, (2017). The first pathway between agriculture and nutrition is the through the income mechanism (quadrant 1), where gains in household income are expected to lead to increased access to food. However, this study is premised on the idea that rural households have little income to afford commercially fortified foods hence the need for using locally available cereals and legumes to value add and fortify so as to enhance micronutrient provision. In rural societies, smallholder agricultural productivity growth and off-farm employment play a pivotal role in income generation, especially in low income developing countries. More so, production diversity at a micro level is key to the availability of diverse set of micronutrients for human consumption. Value addition and fortification play a significant role in improving quantity, quality and diversity of food. Improved household income will therefore lead to improved access to nutritious foods thereby leading to household nutrition. The second pathway (quadrant 2) looks at food access and its impact on micronutrient intake. This channel explores the year-round availability of diverse food at an affordable price. Value addition and fortification ensures all year availability of food products that could only be available during specific times of the year. All year availability is critical to the supply of critical nutrients and thus individual intake of nutrient rich foods is enhanced (Pingali & Sunder, 2017).

This frame work divides these factors into two main pillars which are household-level and individual level factors. This study will use ideas from this conceptual framework (especially quadrant 1 and 3) to try and relate how value addition and fortification can lead to attaining individual nutritional status of people living in the smallholder farming set ups.

2.3 Micro nutrient situation in Zimbabwe

Effects of micronutrient deficiencies impact negatively on social, economic and intellectual development of individuals and communities. Half the population in Africa, including many who consume enough calories and protein lack critical vitamins and minerals according to (WHO, 2006). 350 million women and children in Africa suffer from deficiencies in iron, vitamin A and folic acid. However, most people affected by these deficiencies do not show any clinical symptoms, nor are they aware of these deficiencies, a situation known as hidden hunger. Recent reviews by Gadaga et al., (2009) on micronutrient deficiencies in Zimbabwe, shows that there are recorded incidences of mineral deficiencies at health institutions across the country. Survey data also reveals that vitamin and mineral deficiencies remain problems of public health significance in the country (ZIMSTAT and ICF International, 2012).

Effects of malnutrition often manifest in several forms among children and the elderly. The most common signs of micronutrient malnutrition are stunting (height for age), wasting (weight for height), underweight (weight for age) and overweight. In Zimbabwe, overweight is not common but is slowly getting to be a serious health problem. Key findings from the survey conducted by (ZIMSTATS, 2015) concluded that over a quarter (27%) of children <5 are stunted, 3% are wasted, 8% are underweight, 6%

are overweight. The situation is even worse in rural areas where cases of food shortages are high and also lack of diversified diets are most common. The figure below is a summary of key findings in the research done by ZIMSTATS.

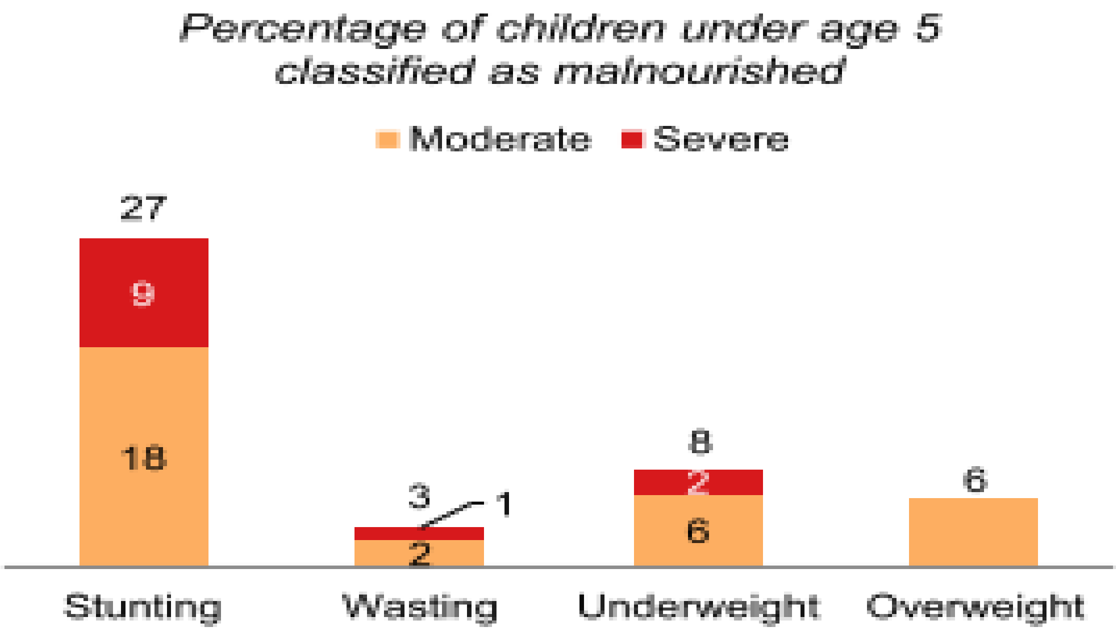

Figure 1.2: Nutritional status of children in Zimbabwe, Adopted from Zimbabwe Demographic Health Survey 2015

Iron deficiency is of public health importance in Zimbabwe. In the world, half of all pregnant women and young children especially in developing countries are affected by iron deficiencies (WHO, 2006). An analysis of haemoglobin levels in school children, pregnant women, lactating mothers and adult males showed that 33% of pregnant women, 29.6% of lactating women, 17.6% of pre-school children and 16.5% of adult males in 4 provinces of Zimbabwe (Mashonaland central, Midlands, Matabeleland North and Matabeleland South) Hb levels between 9 and 11g/dL were found in blood samples of sampled people (ZIMSTATS, 2015). This showed that 9% of the population in the sampled areas had depleted iron stores which help conclude deficiency in iron and a public health concern in Zimbabwe.

Neonatal and maternal mortality are all a common cause of maternal anaemia. National Micronutrient survey of 1999 found out that 31% of woman of child bearing age were anaemic. This was followed by children below age 6 and children 6-14 years (ZIMSTATS, 2015). This is the reason why iron folate supplementation is given to pregnant mothers in Zimbabwe. Key findings from the survey by the Zimbabwe Demographic Health Survey concluded that more than a third of the children aged 6-59 months are anaemic while 27% of women and 15% of men 15-49 are also anaemic. The situation therefore needs urgent attention and value addition and fortification of native cereals plays an important role in alleviating iron deficiency.

While stunting has declined from 33% in 2010 to 26% in 2018, the figures are still above the acceptable global threshold of 20%. According to (ZimVAC, 2013), 35 district are above the national average of 26% while 14 districts are in the high prevalence category, that's according to WHO classifications (30-39%). Stunting reduction programmes therefore need to be scaled up to accelerate reduction of some of the effects of malnutrition.

2.4 Productivity of Small Grains in Zimbabwe

Sorghum (*Sorghum bicolar L.*) and pearl millet (*Pennisetum glaucum L.)* account for 15% of the cereal and 9% of cereal production in Southern Africa (Orr et al., 2016). The dominant grain is maize, which accounts for 70% of cereal grain area, while wheat and rice also have a share of the grain area production. Maize competes directly with sorghum and millets in most cropping systems. Most smallholder farmers grow sorghum and millets in addition to maize on their farms. Maize is generally preferred to sorghum and pearl millet mainly because of the higher yield of maize especially during years of good rainfall. However, during years of poor rainfall, sorghum and pearl millet assures at least a minimum food production that ensures no starvation (Mukarumbwa & Mushunje, 2010).

Sorghum and pearl millet are grown in semi-arid tropics (SAT) mainly because of their drought tolerance. In Zimbabwe, sorghum and millets are staples for most rural households in the low rainfall areas (450 to 650 mm) - agro-ecological regions IV and V in which the study areas of Buhera South and Mt Darwin are located. These regions constitute 70% of Zimbabwe land are drought prone and characterised by high temperatures and poor soils. Productivity of sorghum and pearl millet has been low mainly because of their high competition with maize. Poor low yielding varieties together with lack of investment in breeding for high yielding varieties has resulted in poor competition of these cereal crops on the major markets. The importance of sorghum and pearl millet in a country can be measured in terms of the proportion of the total cereal grain area sown to each crop. The importance of sorghum and pearl millet within each country can be measured in terms of the proportion of total cereal grain area sown to each crop. According to Rohrbach, (1999), Tanzania is the single most important sorghum producer in the SADC region 35% production. Mozambique, Zimbabwe, South Africa and Botswana together account for about 48%. Namibia and Tanzania all account for 27% of pearl millet, while Zimbabwe and Mozambique account for 20% and 7% respectively.

Small grain crops are grown in the poorest and drought prone agricultural regions in Southern Africa (SICNA/ICRISAT, 1998). Normally these are marginalised areas distant from major grain markets. Sorghum and millet cultivated areas has been increasing since 1980 at a rate of 1% and 2% respectively. However, yields for sorghum are relatively low in the SADC region averaging at 0.8t/ha compared to the world average of 1.4t/ha (SICNA/ICRISAT, 1998). In Botswana, sorghum dominates the cropping systems but with an average of 0.2t/ha. Pearl millet average yields are even less than sorghum. In SADC, average yields is at 0.6t/ha, while Tanzania recorded the highest yield of 1.0t/ha. Zimbabwe's yields average 0.3t/ha (SICNA/ICRISAT, 1998). The SADC region produces an estimated 1.5 million tons of sorghum 6% of cereal grains and 0.5 million tons of pearl millet which is 2 % of cereal grains. Zimbabwe accounts for only 11% of total pearl millet production in the entire region.

In Zimbabwe, small grain crops are mainly grown in ecological region IV and V, areas that receive less than 650mm rainfall annually and characterised by poor, infertile soils. These areas are dominated by smallholder farmers who grow the cereals as food security crops. Productivity of these crops has not been far from the figures recorded in the region with sorghum yielding 0.5t/ha and pearl millet figures standing at 0.4t/ha (Second Round Crop and Livestock Assessment Report, 2017). Sorghum and pearl millet cannot compete with maize on the market mainly as a result of their low productivity. This leaves most of the production of these grains for consumption since markets are difficult to access in these semi-arid areas.

2.3.1 Utilisation of small grains (sorghum and pearl millet)

According to a study done by Orr et al., (2016), the consumption of small cereal grains has remained constant as a proportion of total coarse grain consumption. Sorghum and pearl millet accounts for 7% and 3% respectively to the region's calories. In Asia and Africa, sorghum and millets are consumed by humans as food. However, changes in food habits and the inconvenience associated with preparation of small grains compared to fine cereals has reduced consumption trends of the cereal grains (Rao, Christina, & Tonapi, 2016). Furthermore, unavailability of processing technologies and governments failure to craft polices that promote small grains has contributed to the low consumption.

The most common variety for sorghum grown in Zimbabwe is Kafir *(sorghum bicolor Kaffrorum)* and is used as a grain crop. The grain is consumed after boiling the flour to produce foods as *sadza*, porridge in Zimbabwe, *ugali, uji* in East and Western Africa. In Ethiopia, *injera* is the most common food from fermented sorghum dough. The most common consumption option for sorghum and millet in Zimbabwe is sadza which is made from the flour of these cereals. However, poor post-harvest processing methods have contributed to contamination of the flour especially with soil which makes the sadza from these cereals less preferred than that of maize. There is a knowledge gap in assessing proper post-harvest techniques among smallholder farming communities that will ensure clean and safe grain suitable for producing products that are clean and safe for consumption. Another research gap lies in failure to produce more products from these cereals. Flour from sorghum and millets in Zimbabwe is only utilised as food (sadza). Research by (Goworindo, 2012; Dera, 2017) indicate that there is great potential in utilizing value addition for most agricultural products including the marginalised cereal grains among smallholder farmers so that the goals of attaining food security can be achieved. Dera, (2017) even argues that there are relatively few products on the market from small grains (sorghum and pearl millet) other than flour, which is an opportunity this study would like to focus on and try to develop new products that will increase consumption of these cereals.

While a large proportion of sorghum and millet (90%) according to Rohrbach & Mutiro, (1997) is consumed directly as food by humans, adding value to sorghum and pearl millet is critical to increase its production and utilisation (Chandiposha et al., 2013). However, in the poorest countries of the world, pearl millet is a common grain crop. Anti-nutritional factors such as phytate and poly phenols have reduced consumption of crop hence the need for processing to reduce these factors. De hulling, milling and blanching are all possible processing methods that can be employed to reduce the effect of anti-nutritional factors. Flour from milling can be used in the bakery to make bread, biscuits and cakes. However, the dough from this flour is of poor quality due to absence of gluten. Combining wheat flour with small grain flour helps improve quality of the dough. By products of processing produces edible and de-oiled bran which is a good source of dietary fibre. Malted pearl millet is an ingredient in the brewing industry.

2.3.2 Processing of Cereal Grains into other products

Traditional African cereal grains are versatile foodstuffs which can be processed into various food and beverage products. According to Taylor & Emmambux, (2008), there are three main categories of products that can be produced from cereal grains and these are i) whole grain food products which include; rice type, popped and puffed grains, for example *maputi*, meal rice ii) food from flours (fermented and unfermented flat breads, stiff porridges, thin porridges and gruels iii) beverages; non-alcoholic beverages (*mahewu* in Zimbabwe and *Oshikundu* in Namibia), alcoholic (opaque beers), and spirits. The most common products are porridges both thick and thin especially in Zimbabwe. Commercial large scale production is still limited with production of opaque beer from sorghum being an exception. Maize is steadily replacing these cereal grains in this industry mainly because of the ready availability of commercial maize grain on the market (Taylor & Emmambux, 2008). Recent researches (Taylor & Emmambux, 2008; Rohrbach & Mutiro, 1997) have proved that new products are being developed from these traditional cereals. These foods have been developed in recent years targeting the rapidly growing middle-class urban population. Convenience type foods have been developed for example in South Africa; there are several instant sorghum-based porridge products. The sorghum flour is pre-cooked so that to make porridge it is only necessary to stir the flour into boiling water. In east Africa there are many protein and micronutrient-enriched finger millet and sorghum based flours on the market. What characterises these products is that they are based on traditional foods, normally porridges, and often they are acidified with fruit acid to mimic the natural lactic acid fermentation flavour. Such products are available in mostly urban markets which are far from the reach of the rural poor and are rarely found in most smallholder farmer set up despite them being the ones that dominate production of these cereals. Francis Kweku Amagloh, (2012) further concluded that unfortified cereal or legume porridges can lead to deficiencies in micronutrients such as iron and vitamin A among infants as such foods are both low in required nutrients by the body.

Traditional African cereal grains are still chronically underutilized, to the detriment of the wellbeing of the people of Africa and Zimbabwe in particular. The major reason for their underutilization is that they are under-researched (Rohrbach & Mutiro, 1997). Traditional African cereals will fall further and further behind the so-called major cereals in research and this will further increase the knowledge gap. This study will seek to explore all the available options that can be done in order to facilitate processing of cereals products for the benefit of the smallholder farmers. Thus, the challenge for this research on traditional African cereals is to think and act smarter for the betterment of the lives of the smallholder farmers through processing of various products.

2.3.3 Proximate mineral composition of the most common small grains consumed in smallholder farming areas of Zimbabwe

While cereals are rich in nutrients, refining and processing has proved to reduce the quality of these grains. The most common grains consumed as cereals in Zimbabwe include maize, wheat, rice, sorghum and millets and these are the most popularly grown and consumed in all ecological zones of the country. These grains constitute the majority of daily food sustenance. According to Omoniyi and Abdulrahman, (2018), the proximate composition of most cereal crops is similar but the individual crops have peculiar compositions that makes them different from the others. Five food substances (ash, moisture, carbohydrate and protein) are found in different proportions depending on the type of cereal analysed. Some contain large proportions of protein while others contain none. Others have fat, while others are having none. All cereals are characterised by high amounts of carbohydrate and little moisture (Omoniyi and Abdulrahman, 2018). Food composition of foodstuffs is determined using standard analytical methods as defined by the Association of Analytical Chemist (AOAC). A study carried out by Omoniyi and Abdulrahman, (2018), revealed that total carbohydrate in cereals ranged from 75.86% in sorghum to 72.99% in pearl millet. The highest protein in cereals was found in wheat (12.39%) while maize contained only 8.58%. Ash in cereals ranged from 0.56% in rice, 1.67% in millet. Fat and fibre were found in the range 2.50 to 3.94%. Micronutrients such as sodium were found to be the same in wheat and millet (383.33mg/100g) while potassium ranges between 183.33 to 416.67 mg/100g. Zinc ranged from 9.27 to 11.73mg/100g and iron 48.73 to 67.22mg/100g. The table below is a summary of the proximate analysis done to some cereal samples.

Table 2.1: Proximate composition of cereal samples % in Zimbabwe

Cereals	Moisture	Protein	Fibre	Ash	Fat	Carbohydrate
Sorghum	8.04±0.007	10.13±0.020	1.86±0.070	1.41±0.007	2.70±0.035	75.86±0.671
Millet	8.56±0.000	11.03±0.000	3.19±0.010	1.67±0.007	2.56±0.050	72.99±0.326
Maize	9.19±0.140	8.58±0.000	2.83±0.020	1.16±0.010	2.85± 0.020	75.39±0.030
Rice	8.31±0.050	10.49±0.010	1.09±0.000	0.56± 0.050	3.94±0.030	75.61±0.450
RV	<5.00	7-15.00	1.00-7.00	<5.00	<3.00	≥64.00

Values reported were average of duplicate analysis

**RV (*Recommended values)*

Adopted from Abdulrahman and Omoniyi; JAFSAT, 3(2): 50-55, 2016

Table 1.2 Mineral composition (mg/100 g) of samples of some cereals available in Zimbabwe markets

Cereals	Na	K	Ca	Mg	Fe	Zn
Sorghum	350.00±0.0001	400.00±0.001	30.82±0.0015	97.55±0.0043	48.73±0.0007	10.05±0.0018
Millet	383.33±0.002	366.67±0.001	9.00±0.0024	98.18±0.0015	52.87±0.0005	10.95±0.0019
Maize	333.33±0.0011	300.00±0.001	12.95±0.7770	77.62±0.0037	58.35±0.0006	9.45±0.0009
Rice	126.67±0.001	183.33±0.001	3.35±0.0019	23.67±0.0052	59.33±0.0005	9.27±0.0006
RV	296.00	516.00	60.00	76.00	≥16.00	≥3.20

Values reported were average of duplicate analysis

**RV (*Recommended values)*

Adopted from Abdulrahman and Omoniyi; JAFSAT, 3(2): 50-55, 2016

All the samples analysed showed that they were good sources of food as the result obtained were at the recommended standard of sodium, potassium, zinc and iron in the cereals with limit of quantification being in agreement as given by the certified standard reference material (SRM), WHO/FAO in Rome, 2001.

2.4 Productivity of Legume Crops.

Legumes, often called the poor man's meat, contribute significantly to diets of millions of people in the developing countries. Legumes are sources of protein and minerals hence form part of the diet for many vegetarians (Nedumaran et al., 2015). In most developing countries legumes are grown mainly as secondary crops in most cropping systems as rotational crops wit cereal because of their role in fixing nitrogen. However, Nedumaran et al., (2015) argues that the yield and production of these legume crops over the past decades has been stagnant in most developing countries. Abate et al., (2012) also points out that agricultural research and development has focused on yield improvement and productivity of cereal grains and reducing crop losses in order to achieve food security. The diverse role played by legumes in ensuring nutrition security as well as their role in most farming systems means that research in legume crops could impact significantly nutrition security as well as sustainable cropping systems.

Legumes are always behind cereals in production. According to Abate et al., (2012), the area planted to legume crops stand at 27 million hectares in Sub Saharan Africa (SSA) and the estimated annual production stands at approximately 19 million metric tonnes (MT). The average yield of these legumes is less that 1MT per ha which is about 69% of the world average. The major cause of this lag is that legumes are considered secondary crops to cereals in terms of consumer preference and research. The high demand for cereals has pushed the production of pulses to marginal areas of cultivation. These are areas that receive low rainfall and are often characterized by poor soils, a characteristic of most parts of Zimbabwe's smallholder farming areas. The other reason for the lag in legume production is the fluctuations in the price of the pulses which comes mainly as a result of high variability in yield and competition from cereals (Nedumaran et al., 2015). Tropical legume production in Africa is characterised by smallholder farmers whose average household age is around 48, average schooling of less than 4 years and average land size of 0.2ha where land holding is fragmented due to land tenure systems (Abate et al., 2012).

Groundnut is one widely grown legume crop. An estimated 86.6 million people grow groundnuts in SSA region with an average yield of 1000kg per ha. In Zimbabwe, yields vary from about 400 kilograms to several tonnes per hectare depending on production system and production area.

Production ranges from highly commercial to more traditional smallholder production. However, the crop is an important part of the diets of most smallholder farmers who reside in natural regions IV and V by providing an important source of protein and other various products. Production of the crop is therefore dominant in these areas.

Among the pulses, oil seed crops like sesame (*Sesamum indicum L.*) are sometimes preferred to food legumes mainly because of their multiple uses. In Africa, production of sesame stands at 40% of the world's production with countries like Nigeria, Ethiopia and Sudan being ranked highest for producing the crop (Author & Abimiku, 2012). Sesame is mainly produced in the savannas mainly by smallholder farmers on relatively poor soils with limited inputs thus account for the low yields of 300kg/ha (Author & Abimiku, 2012). In Zimbabwe, the crop is one of the marginalised crops and is grown in natural regions IV and V, mostly at household level for consumption and as a cash crop (Munyua et al., 2013). Yields for the crop average 300 to 500kg/ha depending on the management of the crop. However, there is lack of production information for sesame in the country. Current reports from the Zimbabwe Crop and livestock assessment 2017, do not even classify sesame as one of the oil seed crops, which points directly to the argument that the crop is marginalised, only grown and utilised by smallholder farmers in the smallholder farming sector. No production records exist for the crop in the recent past although a few programs like the Livelihoods and Food security Program funded by the UKAID have started commercialisation of the crop among smallholder farmers in Gokwe, Mount Darwin and Guruve districts.

2.4.1 Proximate mineral composition of common legume crops in Zimbabwe

Groundnuts are not only rich in digestible proteins but also rich in vitamins according to Oyerinde, (2017). The principal use of groundnut however, is in the production of oil as well production of peanut butter among others (Oyerinde, 2017). Proximate analysis of the crop has been done by several researchers and results show that legumes are rich sources of proteins (30.12±1.94), fat (42.60±1.81) together with micro nutrients like calcium, potassium, iron and zinc. The table below summarises the proximate composition of groundnut as analysed by (Sampath, 2015).

The reliance on non-nutritive and starchy foods for daily survival by many households that live below the poverty datum line leaves the need for marginalised groups to be equipped with information about some underutilised crops such as sesame that are readily available in their domain. Sesame is a topical annual crop, highly prized of its oil and well adapted to most drought prone areas. Proximate analysis of the crop as analysed by (Ogungbenle & Onoge, 2014) is summarised in table 3 below:

Table 2.2 Proximate composition of most consumed legumes (g/100g)

Component	Chickpea	Pea	Lentil	Broadbean	Bean	Soybean	Peanut
Protein	23.6	21.9	20.6	26.6	21.3	36.9	24.8
Carbohydrates	62.3	52.5	56.4	35.4	47.8	6.1	19.0
Fibre	3.8	10.4	6.83	31.3	18.4	20.9	49.7
Lipids	6.4	2.3	2.15	1.8	1.6	18.1	3.1
Ashes	3.7	3.0	2.8	4.1	4.0	4.7	2.0

(Source: Sanchez-Chino et al., 2015)

Table 2.4 Proximate composition of sesame

Properties	Sesame (g/100g)
Moisture	11.70
Ash	4.03
Fat	40.37
Protein	33.54
Fibre	5.65
Carbohydrate	4.71

Mean values of a triplicate determination

The results in the table shows that sesame seed had (40.37 g/100g) fat, (33.54g/100g) protein, ash (4.03g/100g), moisture (11.70g/100g), fibre (5.65g/100g) and carbohydrate (4.7g/100g). Similar results were also obtained from the proximate analysis of groundnut which shows fat (42.6 g/100g), protein (30.12g/100g), ash (2.51g/100g), moisture (1.57g/100g), fibre (2.70g/100) and carbohydrate (79.01g/100g). The results show that legumes are rich in protein and fat while low in carbohydrates.

Table 2.5 Proximate mineral analysis of sesame and ground is summarised in the table below: (mg/100g)

Mineral	Sesame	Groundnut
Sodium	87.21	42.00
Potassium	96.33	705.11
Calcium	61.37	2.28
Iron	7.29	6.97
Zinc	19.29	3.20

Source: Atasie et al., 2009

The predominant mineral in legumes is potassium. According to Ogungbenle & Onoge, (2014), quantities of K, Na, Mg and CA in legumes were high in the samples analysed. Quantities obtained for micronutrients were enough to meet the nutritional needs for consumers. This gives a conclusion that Groundnut and sesame are potential sources of both macro and micro nutrients. Studies by Ogungbenle & Onoge, (2014) suggest that sesame seed is not harmful to human health due to low levels of anti-nutrients. Legumes are described with many important attributes including high nutritional value, long shelf life and relatively low cost in comparison to animal products hence become affordable sources of protein for rural small holder farmers (Temba et al., 2016).

2.4.2 Utilisation of legumes crops in smallholder farming setups of Zimbabwe

In most rural communities in Zimbabwe, processing and utilization of legumes has a long history linked to women and their traditional livelihood tasks (Chibarabada et al., 2017). There is a great advantage in promoting legumes for improved household nutrition where woman have greater influence over households food choices. Legumes therefore, play a vital role as sources of protein and minerals. Nedumaran et al., (2015) ascertain the point that legume are multi-purpose crops consumed directly as food or as various processed products in many farming systems. Chibarabada et al., (2017) also asserts the fact that grain legumes contribute significantly to diets of rural households that is if consumed as complements of starch. Concern for rural population diets is protein energy malnutrition of which grain legumes play a pivotal role in complementing the dominantly starchy diets.

2.4.3 Legume Food consumption

According to Singh & Diwakar, (1993) groundnuts *(Arachis hypogea)* are consumed as freshly harvested or dry kernels. Harvested kernels can be boiled with or without salt and served as a snack. Post-harvest processing techniques such as shelling produce groundnut haulum used as livestock feed (Chandiposha et al., 2013; Chibarabada et al., 2017). The most popular product from groundnuts is peanut butter which widely consumed in Western and Southern African countries. The butter is used as spread on bread and in the food industry to make various products like candy, cookies and sandwiches (Chibarabada et al., 2017). Another product from groundnuts is oil which is produced from oil extraction process. The oil used in cooking can be processed into margarine and soap making. Candles can also be produced including cosmetics and leather dressing oil. The oil is used in cooking and can be processed into margarine and soap making. The oil can also produce candles, cosmetics and leather dressing oil although on a small scale.

Groundnut cake produced from oil extraction can be used in the bakery industry to make biscuits, bread and cookies. Singh & Diwakar, (1993) state that fermenting the cake improves digestibility of products and this can aid the production of nutritious and tasty products. Groundnuts can also be used to produce milk. Groundnut milk is produced when the nuts are soaked into 1% sodium bicarbonate for 16 – 18 hours. When the milk is fermented it can make yoghurt and can be a substitute of up to 20% in ice cream production (Singh & Diwakar, 1993).

Sesame (*Sesamum indicum)* is one of the oldest, traditional oil seed crop grown for its valued high quality seed oil. The crop is grown for its flavoursome, edible seed and high quality oil. Sesame seed contains high oil content (40-50%), (80-90%) unsaturated fatty acids, 20% protein and various micro nutrients such as vitamins and minerals (Bhat et al., 2014). In Africa, North and central Africa are the predominant producers of the crop with countries like Sudan and Ethiopia topping among many in production of the crop. However, in Sub Saharan Africa, in Zimbabwe in particular sesame is one of the marginalised crops grown mainly at household level in natural region 4 and 5 for consumption and as a cash crop (Munyua et al., 2013). Sesame derives its high value from its many used in both domestic and export markets. The crop is used as additive in the confectionary industry on bread and buns. However, the prime product from sesame is sesame oil. Rich in vitamin E, the oil has medicinal and pharmaceutical value and is being used in manufacture of many health care products (Dossa et al., 2017). The seed is loaded with anti-oxidants, lignans in the form of sesamolin and sesamin which are active ingredients in antiseptics, bactericides and disinfectants. Products of oil extraction are a meal that contains high amount of proteins and calcium which are ingredients in the animal feed industry (Bhat et al., 2014).

In Zimbabwe, not much information is available on the utilisation of the crop especially among smallholder farmers despite the crop being grown in areas dominated by these farmers. The Zimbabwe Crops and Livestock Assessment reports does not qualify sesame crop among any of the oil seed crops hence no information is available on both production and utilization. Available information shows that the most common product from sesame among smallholder farmers in Zimbabwe is sesame butter or

Tahini as it famously called in the northern countries. The butter is prepared by roasting the seed and pounding the seed in a pistil and mortar and other products such as roasted seed saved as a snack with some salt. Very little to none is done in terms of oil extraction especially with smallholder farmers. Some of the major reasons include lack of knowledge on value addition for the crop and coupled with non-availability of machinery necessary for oil extraction (Dera, 2017). Much of the sesame produced by smallholder farmers is sold to middlemen and companies despite the huge potential the crop has in terms of improving household food security and nutrition.

2.5 Micronutrients of International and National Public Health Concern

The World Health Organisation (WHO) and UNICEF have identified iron deficiency anaemia (IDA), vitamin A deficiency (VAD), iodine deficiency disorders (IDD) and zinc deficiency as the four micronutrient deficiencies of greatest significance (Solomon, 2005). The two international organisations linked the deficiencies with high prevalence of childhood diseases and mortality. The deficiencies also have negative impacts on general growth and development, reproduction, maturity and immunity responses. Micro nutrients necessary for human nutrition include among others, iron (Fe), Zinc (Zn), Manganese (Mn), Selenium (Se), Fluorine (F) and Iodine (I) (Solomon, 2005) which unlike proteins and vitamins, cannot be synthesized in the body, and therefore must be obtained through dietary means. The amount of mineral in an animal tissue reflects the amount of the mineral in the diet or food consumed by the animal, which translate to the mineral in the food consumed. Absence of these micronutrients in diets have significant impacts on the normal growth and development of the human body hence the need to address such shortages (Solomon, 2005).

2.5.1 Micronutrients of public health importance in Sesame

Iron deficiency, is the most prevalent micronutrients of public health concern in the world, affecting at least half of all pregnant women and young children in most developing countries. Under 24 months children are at risk of anaemia which has effects of stunting their growth and reduces their ability to resist common childhood illnesses. Iron deficiency in older children affects the abiliy to concentrate and perform well in school while in adults anaemia is a serious threat to mothers at child birth. According to WFP, (2006), every day some 140 women die in childbirth because of severe anaemia. Anaemia also impairs the health and labour productivity of working adults in general. According to Bamigboye et al., (2010), 100 g of sesame contains 97 µg of folic acid, about 25% of recommended daily intake. Folic acid is essential for DNA synthesis. When given to expectant mothers during their peri-conception period, it may prevent neural tube defects in the new borns. Sesame therefore becomes a rich and important source of this mineral which is of great importance to human health.

Magnesium is an essential element in human health and known advantages of magnesium in human nutrition include preventing the airway spasm in asthma, lowering high blood pressure, contributory factor in heart attacks and diabetic heart disease. Sesame seed has substantial amounts of this mineral (351 mg/100g of seed) which becomes an important source of the mineral.

Table 2.6 Mineral composition of sesame seed

Principle	Nutrient value	Percentage of RDA
Calcium	975 mg	98%
Copper	4.082 mg	453%
Iron	14.55 mg	182%
Magnesium	351 mg	88%
Manganese	2.460 mg	107%
Phosphorus	629 mg	90%
Selenium	34.4 µg	62.5%
Zinc	7.75 mg	70%

(Source: USDA National Nutrient data base)

Calcium is important for bone, teeth and muscle development. 99% of calcium is stored in bones and teeth while 1% is stored in muscle. Legumes are a rich source of calcium together with leafy vegetables, fish, bones and dairy products. Sesame seed has about 975 mg/100g which is a relatively high amount (Bamigboye et al., 2010). Addition of sesame to diets lacking calcium will improve levels of calcium in such diets.

Just like other minerals such as manganese, zinc acts as cofactor in many enzymes and is an integral part of many metallo-enzymes such as alcohol dehydrogenase, alkaline phosphatase and carbonic acid. Zinc plays a pivotal role in metabolic pathways and in diets of humans is essential for optimal growth and health. Signs and symptoms of this mineral deficiency in the diets include poor weight gain, impaired linear growth, reduced deposition of lean body tissue, hypogeusia impaired immune-competence and anorexia (Bamigboye et al., 2010). Concentration of zinc in sesame is around 19.29mg/100g making it a very good source of the mineral in diets. Zinc therefore is considered one of the most essential minerals in foetal and early childhood development mainly because of its role in biochemical processes of growth and development (Solomon, 2005).

Concentration of phosphorus in sesame according to Ogungbenle & Onoge, (2014), stands at around 629 mg/100g of seed. Phosphorus is an important micronutrient in human diets as it used for growth and repair of body cells and tissues. Phosphorus is also required for a variety of biochemical processes including energy production and pH regulation. Phosphorus is used in the body for energy production in the form of adenosine triphosphate (ATP). This is an active form of energy and only available in the body in small quantities. Phosphorous is also used in the formation of deoxyribonucleic acid (DNA) and it's a component of DNA. Without sufficient levels of phosphorous the body may fail to synthesize enough protein and this affects the overall body health. With a substantial amount of the mineral in sesame, this gives the crop a huge potential to be used as potential micronutrient fortificant in cereal-legume based diets. The seeds are incredibly rich sources of many essential minerals. Just a handful of sesame a day provides enough recommended levels of phenolic anti-oxidants, minerals, vitamins, and protein that the body requires.

2.6 Value Addition and Food Fortification of Small Grains among smallholder farmers

Value addition to any agricultural product involves the process of increasing economic value and consumer appeal of that particular agricultural commodity (Choudhury et al., 2012). Value addition involves production of a commodity for a particular market, changing its form before marketing, changing how a commodity is packaged and branded for the market, changing the way a commodity is marketed, or even adding a new enterprise to an existing one (Goworindo, 2012). Food fortification on the other hand involves the practice of deliberately increasing the content of essential micronutrients, i.e. vitamins and minerals (including trace elements) in a food, in order to improve the nutritional quality of the food supply and provide a public health benefits with minimal risk to health of would be consumers (Liu et al., 2014). Fortification of cereal grain foods has been regarded as an effective strategy that can be used to overcome nutrient deficiencies particularly among smallholder farmers in semi-arid regions. Micronutrient deficiencies, especially of vitamin A, iron, iodine, and zinc, have been widely reported to be prevalent in both developing as well as some developed countries. Food fortification is dependent on existing food production and distribution systems and requires little external support. This is crucial in addressing challenges of food fortification at household level. There is very little information on the use of food legumes in value addition and fortification of native cereals with special focus on the smallholder production, processing and marketing in Zimbabwe. Food legumes are grown traditionally for consumption in natural regions 4 and 5. In Zimbabwe, there are few to no available options on the market of nutrient supplement that can be used by the general populace for food fortification especially in rural areas. The potential benefits of fortifying native cereals using food legumes especially sesame, groundnuts and cowpeas are unknown as this has not been explored before in Zimbabwe. According to statutory instrument 120 of the Government of Zimbabwe (2016), the current fortification programme in Zimbabwe is targeting edible vegetable oil, salt, sugar, maize meal and wheat flour as the main vehicles. Very little to non-effort has been made to do value addition and fortification of native cereals which are the major food vehicles of smallholder farmers. Hence the focus of this study is to explore fortification of cereals using sesame and groundnuts so as to improve essential micronutrient content in cereal based porridges. This is because most smallholder communities in rural areas are missing out on the potential benefits of value addition and fortification, as currently there is no deliberate effort by Government assist in improving variety of consumption of native cereals which are staples for most smallholder communities.

2.7 Nutritional quality of value added products from cereals and legumes.

According to Igbabul *et al.*, (2018), one of the key elements of value added products is the nutritional quality of the value added products. While addressing micronutrient malnutrition is key, there is need to make sure the products from value addition are well balanced to supply the required macro and micro nutrients to the consumers. Millet based food products are highly nutritious and are known to have high nutrient content which includes protein, essential fatty acids, dietary fibre, B-Vitamins, minerals such as calcium, iron, zinc, potassium and magnesium (Rao et al., 2016). These nutrients need to be present in appropriate amounts in the food products so that the objective of eradicating micro nutrient malnutrition can be achieved. The basic nutrients that are critical for value added products are protein, fat, dietary fibre and essential micro nutrients.

Demand for millets for direct consumption has been declining in the recent past due to changing food habits and the inconvenience attached with food preparation compared to fine cereals. Poor processing technologies and government policies that do not promote millets while favouring supply of fine cereals at subsidized prices has also contributed to low demand for millets. Millets are known for their nutrient richness and also characteristics of drought tolerance and resilience to climate change. Developing technologies that makes millet value added products available as convenient to make and easy access at reasonable prices will find great demand and market particularly in urban places where there is growing conscious for nutritive intake of food.

2.7 Sensory preferences and Palatability

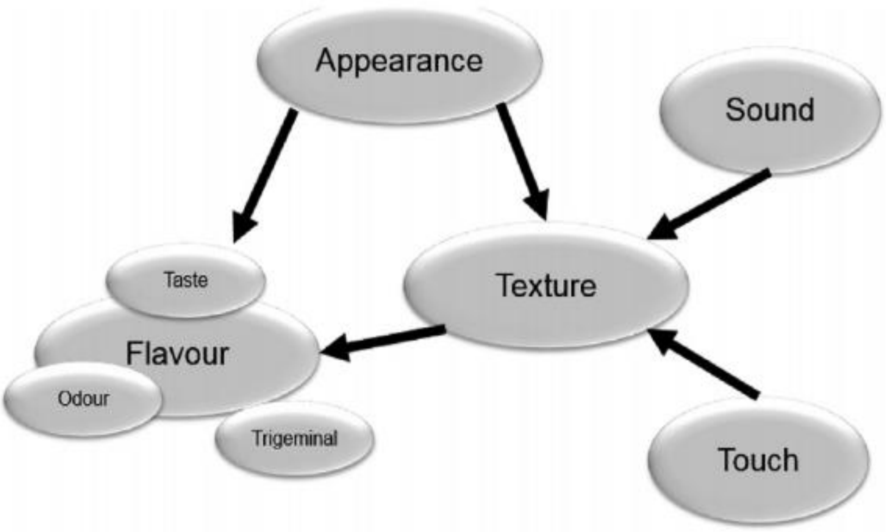

Figure 2 Five main human senses and their interactions: Adapted from (Muhimbula et al., 2011). Formulation and sensory evaluation of complementary foods from local, cheap and readily available cereals and legumes in Iringa, Tanzania

The sensory properties of food determining palatability are taste, smell, texture, temperature, visual appearance and overall acceptability by the consumers (de Bouillé & Beeren, 2016). Palatability of food is measured using either visual analogue scales (VAS) or fixed point scales (FPS) where subjects are asked questions like 'how pleasant have you found the food?', 'how satisfying have you found the food?', 'how palatable is this food?', 'how attractive do you find the food?' or 'how much did you like the food?' Palatability is classified according to how pleasant or well liked the food is. The more pleasant or liked, the higher the palatability. The palatability of food is often assessed by taste tests pleasantness ratings, where a small sample of food is tasted and swallowed or by using taste-and-spit pleasantness tests, where the food samples are tasted and then spit out. Investigations of whether these tests can predict consumption.

Most often used in appetite research are VAS, in the form of horizontal lines of varying length, with words anchored at each end, describing the extremes of a unipolar question (for example a 9 point hedonic scale with (9) = extremely like and (1) = extremely dislike. Subjects are asked to make a mark across their corresponding to their feeling at the present time (Flint et al., 2003). Quantification of the measurement is made by measuring the scores gained by each product from the subjects. The subjects are asked about their appetite for a meal or their feelings of hunger, desire to eat, satiety, fullness and prospective food consumption, with text expressing the most positive and most negative rating anchored at each end. According to (Lb et al., 2003) it was concluded that VAS show some ability to predict aspects of feeding behaviour and act as a useful adjunct to measures of food, energy and nutrient intake. VAS show sensitivity to experimental manipulations and show good reproducibility provided that they are used in within-subject designs.

2.8 Summary of literature Review

Small cereal grains (sorghum and pearl millet) are still under-utilised under smallholder farmer set ups despite their nutritive value. Small grain cereals constitute the bulk of the food consumed in marginal smallholder farming areas. Cereals are sources of energy (carbohydrate) although other nutrients like protein and minerals are available. Small grains therefore, are generally low in protein and are limiting in some essential amino acids, particularly lysine and tryptophan. Bulk of the diet in smallholder farming areas is based on starch and therefore presents risks of malnutrition to the consuming communities. While productivity of these grains is second to maize production, there is high potential that if utilised well they can help the fight against micronutrient malnutrition by making use of the nutritive value of these small grain cereals. Legumes are rich sources of the limiting amino acids that are not found in cereals. While animal protein sources are the best, their availability especially to the economically poor rural communities is very expensive. Legumes therefore stand as cheap and alternative sources of proteins as well as other important minerals that are of human health significant. Supplementation of cereals with locally available legumes rich in protein and lysine, although, often limiting in sulphur amino acids, increases the protein content of cereal-legume blends and their protein quality through mutual complementation of their individual amino acids. Use of local foods formulated in the home and guided by the following principles: (i) high nutritional value, (ii) acceptability, (iii) low price, and (iv) use of local food items is critical in the view that both macro and micro nutrient deficiencies are a public health threat and need to be addressed. Inexpensive, locally available and nutritious complimentary foods therefore makes composite cereal-legume blends potentially effective in solving some of the nutrition problems facing infants, children and even the elderly in rural communities of Zimbabwe.

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CHAPTER 3
METHODOLOGY

3.1 Introduction

The chapter presents research methodology for the study. In particular, the chapter explains the research design and the selected procedures for the development of the fortified porridge from sorghum, pearl millet, groundnuts and of particular importance sesame. It also describes process of raw material collection, sorting, and blending to produce the different combinations of the porridge blends. In addition to that the chapter explains the measurements taken with regards to the different proximate analysis done on both the raw material and the product. Quadrant 3 of the conceptual framework in chapter 2 is the key guiding factor in this chapter. Ensuring all year access to health and nutritious food is achieved by improving dietary diversity. Value addition and fortification therefore play a significant role in achieving this goal. The different combination tried in this chapter during product formulation all seek to provide all year access to health and nutritious diet for the attainment of individual household nutrition.

3.2 Research design

The study employed a quantitative research technique through controlled experiments. A simple Complete Randomized Design (CRD) was used during the allocation of quantities for the different raw materials in treatment formulation. Several combinations were tried until six were selected in this study. Quantitative data collection methods were used in this study and results were presented in tables and figures.

3.3 Sampling for collection of raw materials

Simple random sampling was used to select which farmers to purchase the raw materials. Mbare Musika is one big farmers market where produce from different farmers in the country is marketed. More than 100 farmers sell their produce at the market. Out of the total population of 50 middlemen selling sorghum, pearl millet, groundnut and sesame, 10 traders selling the selected raw materials were randomly selected. Out of the 10 only 3 were to be selected for procurement of each of the raw materials. Ten cards (3 with YES and 7 with NO) were given at random to farmers selling the products and only the farmer with a YES card were picked for purchase of the raw materials. Three samples of each (sorghum, pearl millet, groundnuts and sesame) (10kg) were bought and made into one composite sample of each type of sample which was homogenised as shown below:

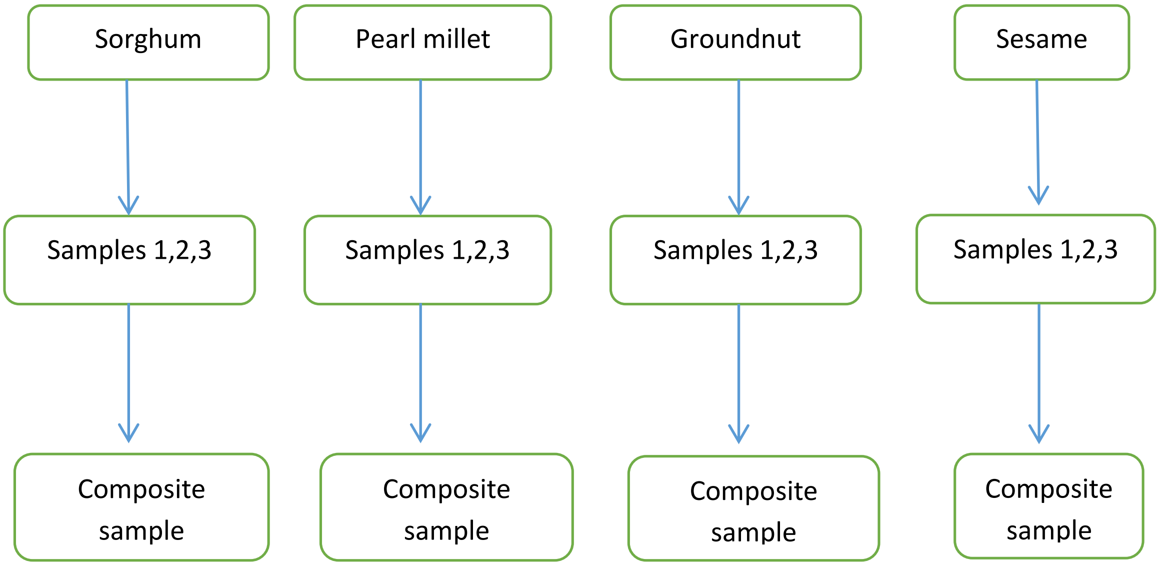


Figure 3 *Samples for laboratory analysis were collected from the homogenised composite samples.*

3.3.1 Development of the sesame fortified porridge

The raw materials used in the study (Sorghum, pearl millet, groundnuts, sesame) were purchased from a local market in Mbare, Harare Zimbabwe. The raw materials were cleaned manually to remove dirt, dust, damage seeds, seeds of other crops and foreign matter.

3.3.2 Roasting

Bioavailability of the nutrients in small grains is restricted by the presence of anti-nutritional factors such as phytic acid, tannins, goitrogens, oxalic acid and trypsin inhibitors (Jalgaonkar & Sharma, 2016). These compounds interfere with mineral bioavailability, carbohydrates and protein digestibility through inhibition of proteolytic and amylolytic enzymes, hence the need for pre-treatment of grains before processing. After cleaning the samples 5kg of sorghum and pearl millet were roasted/pre-heated at 70^{o}C for 10 min and left to cool at room temperature. Pre-heating/roasting was done to increase digestibility, bioavailability of vitamins, minerals, amino acids, proteins and phytochemicals, and decrease anti-nutrients and starch (Muhimbula et al., 2011). The cereals were then milled using a Deluxe Blender AE-099 and sieved through a screen No 1 for fine and uniform particles. Legume seeds (groundnuts and sesame) were cleaned to remove breakages and foreign material which would spoil the flour. The legumes were roasted at the same temperature of 70^{0}C with variations in time for roasting (10 min and 20 min). Due to limitations with regards to equipment used the only variation was left to be time taken to roast rather than changing the temperature. Groundnuts were decorticated after roasting. The clean groundnuts and sesame were stored in a dry plastic container waiting for milling into flour.

3.3.3 Milling

Cereal grains and legumes instantized by roasting treatment were coarse grinded using a Deluxe Blender AE-099 and sieved through ISI Mesh No.1 (1 mm) to obtain flours of uniform particles size.

3.3.4 Blending

The mixing ratios used were similar to the ones used by (Muhimbula et al., 2011) with some modification. Six foods mixes were formulated by mixing different ratios of staples and protein supplements and labelled as B1- B6. The mixture were obtained by blending different components of food selected from staple and protein supplements in appropriate ratios required to achieve a proper food mix that meets energy and protein requirements of children from the age of 6 months (292kcal and 8% protein) (Dewey and Brown, 2003). The ratios of mixing were calculated using the method described by (Muhimbula et al., 2011) where the ratio of inclusion for cereals was from 50% to 90% and that of legumes ranged from 10% to 30%. The following ratios were formulated (Sorghum: Pearl millet: Groundnut: Sesame) (**B1**) 60;0;20;20 (**B2**) 0;65;25;10 (**B3**) 60;20;15;5 **(B4)** 80;0;0;20 **(B5)** 0;70;0;30 **(B6)** 0; 75; 10;15 (6 treatment levels). These were compared to a traditional straight sorghum porridge used as control. The treatments were supplemented with sugar as energy supplements to improve the sensory attribute of the formulated foods and some salt. Each treatment of mixed composite flour was thoroughly mixed in order to achieve uniform mixture of legume flours with sorghum and pearl millet flour. The ingredients were mixed in Deluxe Blender (AE-099 model) at full speed for 5 minutes to obtain six different samples as shown in table 3 below:

Table 3.1 Blend formulations for the porridge

Main Ingredients	Formulation name	Mixing ratios (in grams)
Sorghum, groundnut, Sesame	B1	60g Sorghum + 20g Groundnut + 20g Sesame
Pearl Millet, groundnut, Sesame	B2	65g Pearl millet + 25g Groundnut + 10g Sesame
Sorghum, Pearl Millet, groundnut, Sesame	B3	60g Sorghum + 20g Pearl millet + 5g Groundnut + 15g Sesame
Sorghum, Sesame	B4	80g Sorghum + 20g Sesame
Pearl Millet, Sesame	B5	70g Pearl millet + 30g Sesame
Pearl Millet, Sorghum, groundnut, Sesame	B6	60g Pearl millet + 10g Sorghum + 15g Groundnut + 15g Sesame
Sorghum	Control	100g

KEY- Roasting times for groundnut and Sesame in the formulations

B1- Groundnut roasted at 70^{o}C for 20min, Sesame roasted at 70^{o}C for 20min

B2- Groundnut roasted at 70^{o}C for 20min, Sesame roasted at 70^{o}C for 20min

B3- Groundnut roasted at 70^{o}C for 10 min, Sesame roasted at 70^{o}C for 20min

B4- Sesame roasted at 70^{o}C for 10min

B5- Sesame roasted at 70^{o}C for 20min

B6- Groundnut roasted at 70^{o}C for 10min, Sesame roasted at 70^{o}C for 10min

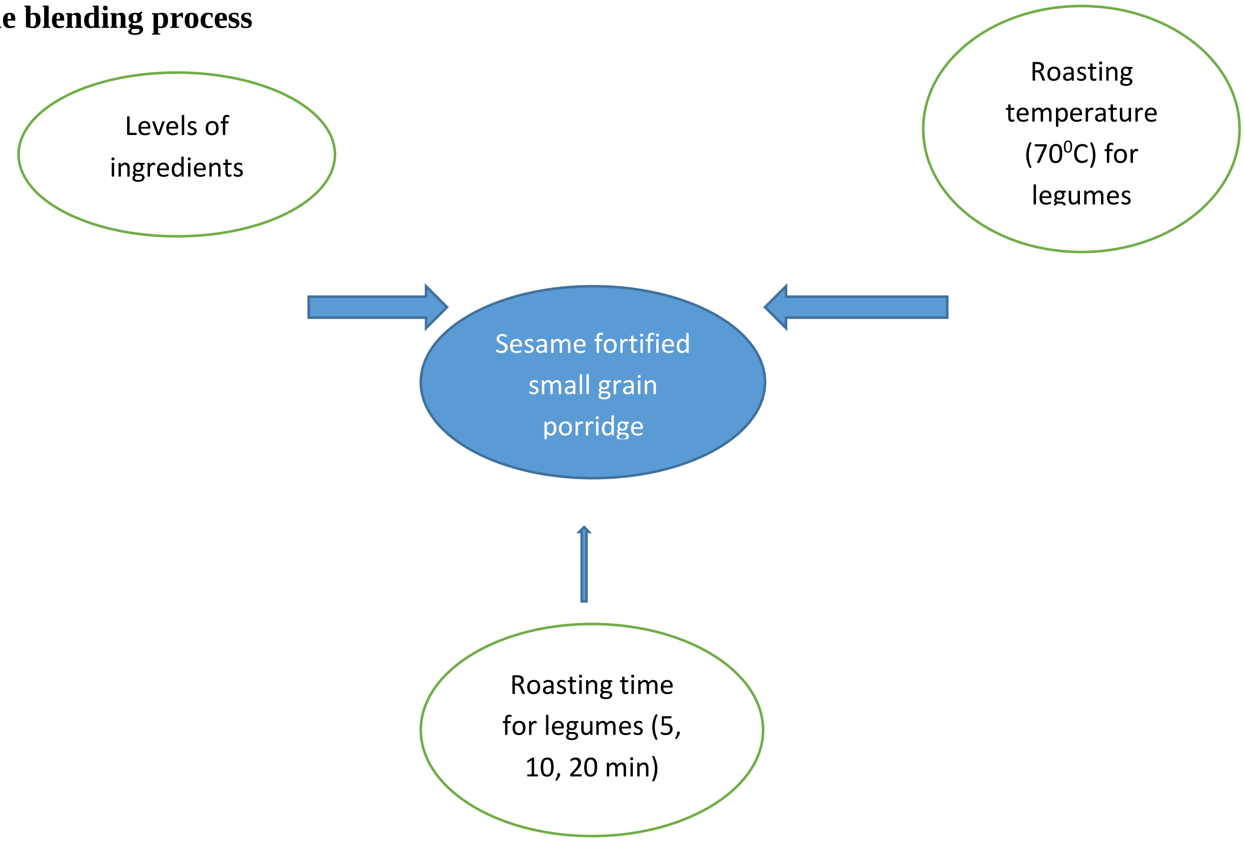
The formulations were exposed to sensory evaluation and the most superior was then taken for proximate analysis.

Figure 3 Picture of the samples of the fortified porridge blends

3.3.5 Preparation of porridges

The porridges were prepared from composite flours using the standard recipe. Flour -100g, water -300ml, and sugar -20g. About 250ml of cold water was poured in a pot and placed on fire and 100g of each flour blend was added into the warm water in the pot. The mixture was stirred with a wooden stick to avoid lumping and cooked for 30-35mins until it thickens. The porridge was left to simmer for 5min before being served. 20g of sugar and some salt 4g was added to improve the taste.

The blending process



Key: Independent variable

Dependent variable

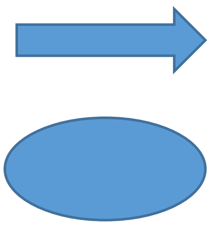


Figure 4: Conceptual framework for product formulation.

Product development chart

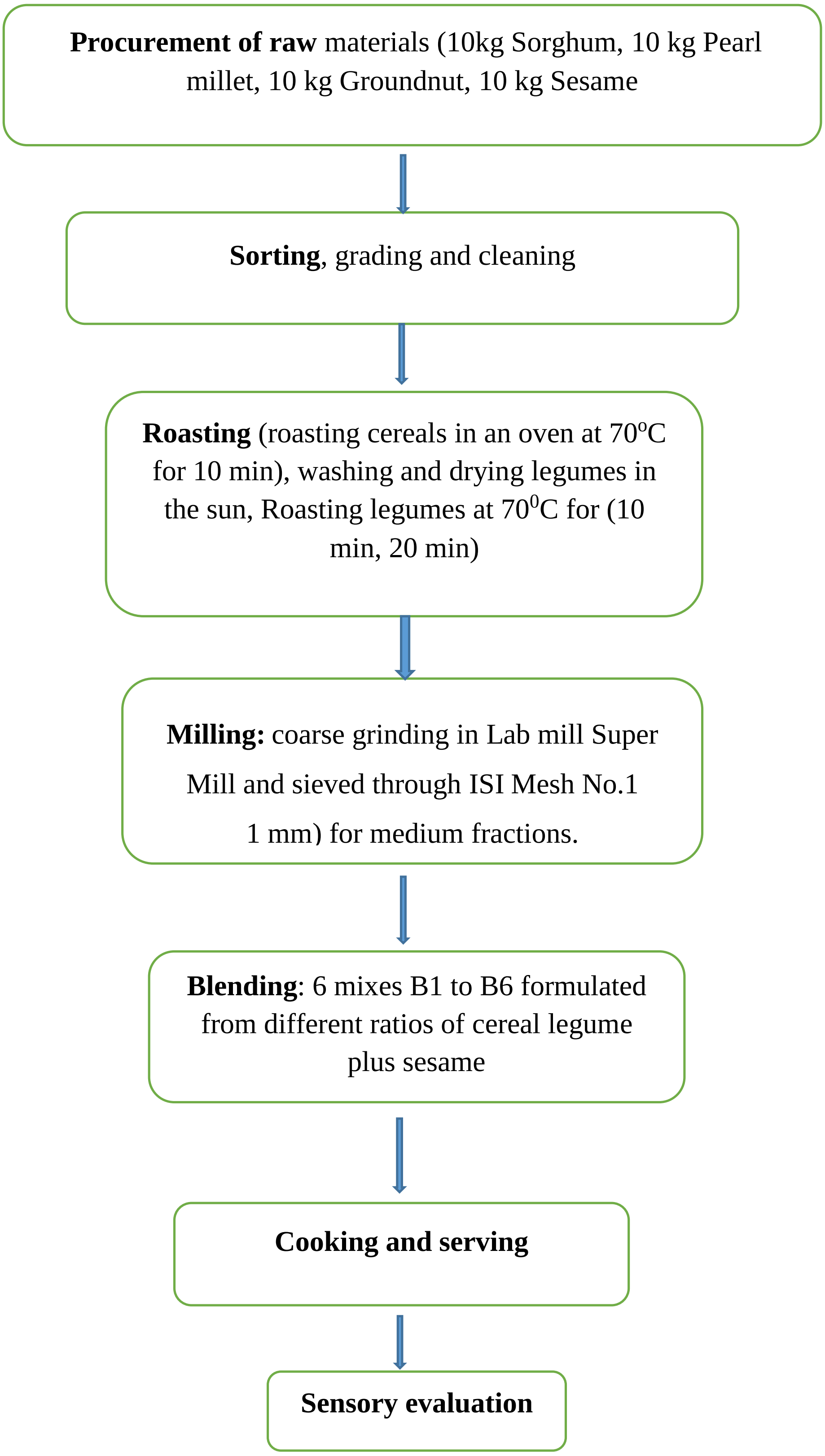


Figure 5: Process flow for product development and analysis

3.4 Measured parameters

3.4.1 Proximate analysis of ingredients and the product

Proximate composition of the raw materials and the multi grain cereal and legume - sesame blend were carried out using the Association of Analytical Chemists (AOAC, 1998) method. The parameters analysed include; ash, moisture, crude fibre and protein content. Carbohydrate was calculated by difference according to the method described by (Igbabul, Ogunrinde, & Amove, 2018).

3.4.2 Determination of ash

Ash is the organic residue remaining after the water and organic matter have been removed by heating in the presence of oxidizing agents. This provides a measure of the total amount of minerals within a food. The method described by Igbabul et al., (2018) was used for the determination of ash. Samples of 1-10g were used in the analysis. 150 grams of raw samples were finely ground and then carefully mixed to facilitate the choice of a representative sample of 1.5 grams. In triplicate, the samples were pre-ashed in a crucible, usually made of silica/porcelain. The food matrix was destroyed by heating gently in a heating mantle to char the sample and then at 550 °C for 4 hours in a muffle furnace to prevent foaming of lipids (and sugars) until a white (or light grey) residue was produced. The food samples were weighed before and after ashing to determine the concentration of ash present and expressed as below:

$$\%\ \text{Ash (dry basis)} = \frac{M_{ASH}}{M_{DRY}} \times 100$$ ……………………………………..Equation 1

Where, M_{ASH} refers to the mass of the ashed sample, and M_{DRY} refer to the original masses of the dried samples.

3.4.3 Determination of moisture by evaporative means

The standard method of AOAC (1990) was used to determine the moisture contents of the experimental samples. The moisture content is determined by measuring the mass of a food/sample before and after the water is removed by evaporation:

$$\%\ \text{moisture} = \frac{(W_1 - W_2)}{W_1} \times 100$$ …………………….Equation 2

Where: W_1 – weight (g) of original sample before drying and W_2 – weight (g) of sample after drying. The basic principle of this technique is that water has a lower boiling point than the other major components within foods, *e.g.*, lipids, proteins, carbohydrates and minerals. Empty evaporating dishes were thoroughly cleaned in 0.1N Nitric acid, rinsed with deionised water and dried in the oven at 105^0C for 1 hour before being cooled in desiccator. The evaporating dishes were weighed on a top loading balance and weight recorded. 20g of each of the raw samples were weighed into the evaporating basins in triplicates. After air drying for two hours at room temperature, the weighed samples were placed in an oven and dried for 3 hours at 105^0C. After drying, the evaporating dishes were transferred into a desiccator to cool. The dishes with the dried samples were reweighed (AOAC, 1998).

3.4.4 Determination of protein

The principle behind the test is that there is total digestion of all nitrogenous compounds in the samples to ammonium sulphate by concentrated sulphuric acid according to Ojali et al., (2015). The Kjedhal method was used for the determination of protein. In duplicate, 1.5 grams of the sample were measured and put in a 500ml Kjedhal flask. 4 grams of Kjedhal catalyst and 25mls of concentrated sulphuric acid were added to the flask containing the sample. Digestion of the sample using heat for 1 hour was carried out until the contents of the flask were clear. The samples were left to cool. 300mls of distilled water were added to the cooled sample and 100mls of 40% sodium hydroxide was added to neutralise the solution. The neutralised solution was then distilled into a beaker containing boric acid (mthly violet stained). Ammonia (NH_3) produced during distillation was collected as ammonium hydroxide (NH_4OH) in boric acid with colour green. The boric acid solution was titrated against standardised 40% HCL until a colour change from green to purple was noticed determining the end point of titration. The amount used in titration was then used to calculate the percentage protein:

$$\% \text{ protein} = \boxed{\frac{(A-B)}{W1} \times N \times 0.014 \times 6.25 \times 100} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{Equation 3}$$

Where: A = volume (ml) of 0.2 N HCL used in sample titration

B = volume (ml) of 0.2 N HCL used in blank titration

N = Normality of HCL (0.2)

W1 = weight (g) of sample

0.014= milli equivalent weight of nitrogen

6.25= the protein nitrogen conversion factor for cereals and legumes

3.4.5 Determination of crude fibre

This was carried out according to the procedure of AOAC (1980). Three grams of each moisture-free sample was weighed into a 250ml beaker, and 50ml 4% H_2SO_4 added followed by distilled water to a volume of 200ml. This was then heated to boiling and kept boiling for exactly 30 minutes, with constant stirring using a rubber- tipped glass rod to remove all particles from sides of beaker. The volume was kept constant by addition of hot distilled water. After 30 minutes of boiling, the content was poured into a Buchner funnel fitted with an ash less Whatman filter paper No. 40 and connected to a vacuum pump. Beaker was washed several times with hot distilled water and then transferred quantitatively with a jet of hot water. Washing continued on the funnel until the filtrate was acid-free as indicated by litmus paper. The acid-free residue was transferred quantitatively from the filter paper into the same beaker removing the last traces with 5% NaOH solution and hot water to a volume of 200ml. Again the mixture was brought to boil and kept boiling for 30 minutes with constant stirring as earlier described, keeping the volume constant with hot water. The mixture was then filtered and washed as earlier described until alkaline free. Finally, the resultant residue was washed with two portions of 2ml 95% alcohol. Residues on filter paper were transferred to a pre-weighed porcelain crucible. The content of the crucible was then dried in an oven maintained at 110^{o}C to a constant weight after cooling in a desiccator. Crucible content was then ignited in a muffle furnace at 550^{o}C for 2 hours, cooled and weighed. Duplicate determinations were carried out on each sample. Crude fibre was calculated as loss in weight after ignition. Loss in weight between digested and ashed sample equals crude fibre and was expressed as % present in the original sample on a moisture-free basis.

3.4.6 Determination of fat

Fat plays an important role in many foods. Fat contribute to the flavour of food as well as it gives texture and also mouth feel to the food. It is an important component which gives us maximum energy. Clean glassware was rinsed with hexane and dried in an oven at 102^{o}C for 30 minutes and cooled in a desiccator. Fat analysis was done according to the Soxhlet extraction method where 3 grams of grounded and dried sample was placed in a thimble which was weighed without sample. Weight of the thimble plus sample was also recorded. The thimble with cotton on top was then placed in a Soxhlet apparatus. 200 ml of hexane was added to a round bottom flask (250ml) which was weighed on a top loading balance. The extraction unit was assembled over a heating mantle and the hexane was set to heating until the hexane started boiling. The source of heat was adjusted (30^oC) so that the solvent dripped from the condenser into the sample chamber at the rate of about 6 drops per second. The extraction was done for 6 hours until all the lipids in the sample were removed by the solvent. After the extraction process, the thimbles were removed from the Soxhlet apparatus and dried in an oven for 30 min at 102^oC, cooled in a desiccator and re-weighed. Total fat in the sample was calculated as follows: Weight of thimble + sample before extraction = W_1: Weight of thimble + sample after extraction = W_2

Then crude fat percentage = $\frac{(W_1-W_2) \times 100}{W_1}$ ………………………….Equation 4

3.4.7 Determination of carbohydrate

Carbohydrate was calculated by difference and the energy content by a method described by (Igbabul et al., 2018). Constituents in the food (protein, fat, water, alcohol, ash) were determined individually, summed and subtracted from the total weight of the food. This is referred to as total carbohydrate by difference and was calculated by the following formula:

100 - (Weight in grams [protein + fat + water + ash + alcohol] in 100 g of food).

3.4.9 Micronutrients analysis (Iron, Zinc, Calcium, Manganese and Potassium)

The method described by Bamigboye et al., (2010) was used for analysis of the micronutrients in both raw samples and the product. Potassium (K), Calcium (Ca), Iron (Fe), and Zinc (Zn) analysis was carried out using an Atomic Absorption Flame Emission Spectrophotometry (AA-6701F). Previously ashed samples were added with 10 ml of concentrated HNO_3. The beakers were left to digest overnight. Samples were then heated in a water bath until a clear solution was obtained. The solution was allowed to cool, filtered and transferred into 50ml volumetric flasks and diluted to the mark with distilled water. Standard stock solutions with concentration of 1000mg/L for Calcium, Potassium, Zinc, Iron, Magnesium and Phosphorus were obtained from Merck (Germany). Working standards for the metals were prepared by serial dilution of the standards solutions. Certified Standard Reference Material Number BCR- 191 provided by the institute of reference Materials and Measurements of the European Joint Research Centre was used for the method and results validation (AOAC, 2005).

3.5 Sensory evaluation

Samples were subjected to sensory evaluation using a panel of one hundred semi-trained evaluators randomly selected from the university community. Samples **B1, B2, B3, B4, B5** and **B6** of the sesame fortified porridge were used for sensory evaluation. The sample were cooked and served hot and evaluated for sensory attributes using a 9-point hedonic scale: (9 =extremely liked to 1= extremely disliked), (de Bouillé & Beeren, 2016). Panellists rated the product for overall acceptability and sensory attributes of appearance, taste, flavour and texture.

3.6 Data Analysis methods

An analysis of variance at 5% significance level was used to analyse the data which was managed using Statistical Package for Data Analysis (SPSS version 20). For sensory evaluation, quality parameters, A Kruskal Wallis H test was used to allow comparison of the independent treatments and means were separated using the LSD test. Results were presented in the form of tables, graphs and pictures Christensen *et al.,* (2015).

3.7 Ethical considerations

Ethics of food production and consumption were observed as according to (Korthals, 2007). Food, is and continues to be an intrinsic good for consumers. Some food has not only monetary value, but cultural, social and ethical value as well, because it has an intrinsic role to play in individuals experiencing life according to their ideas of what constitutes a good life. Clear guidelines in terms of product ingredients and relevant information on the products were followed in order to avoid conflicting and potentially untrustworthy information being presented to consumers. Consent was sought from individuals who participated in sensory taste and evaluation.

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CHAPTER 4 Results

Formulation and proximate analysis of raw materials and formulated fortified porridge made from sorghum, pearl millet, groundnut and sesame

Abstract

The proximate macro and micro nutrient composition of a fortified porridge made from sorghum, pearl millet, groundnut and sesame were chemically analysed using the methods defined by the Association of Analytical Chemist (AOAC). Calcium, iron and zinc in the cereal and legume samples were determined by flame Atomic Absorption Spectrophotometer while potassium in the samples was determined using flame photometer. The results obtained for the raw materials showed that the available carbohydrate was high in cereals in the range of 40.57% in sorghum to 41.83% in pearl millet. Legumes had lower carbohydrate values in the range of 4% sesame and 12.96% groundnut. Legumes had the highest protein content (25.5%) for groundnuts, while cereals contained between 8.55-9%. The ash content ranged from 4.44% for sesame to 4.6% for groundnut while cereals had a higher ash content of 38.89% for pearl millet. Fat was found to range between 40 to 53% and fibre was between 3 and 9% across the cereals and legumes. An appreciable amount of calcium (221.07%) was found in sesame while potassium was high in all the samples. Iron and zinc was found in appreciable amounts across the samples although the minerals were significantly high in sesame. The product was also analysed and results obtained indicated that there was significant $p<0.05$ protein increase in the product compared to the control. Protein ranged from 14.72% to 20.12% for the six blends an indication of the contribution of legume protein in the composite diets. There was no significant difference ($p<0.05$) in carbohydrate content of the formulated porridges. Fat was highly significant in the product ranging from 35 -49.5%. The high fat content could have been a function of fat from the legumes as the raw materials. Moisture was significantly low in all the porridge flours (3.95-4.44%). Ash and fibre was less than 5% across the formulated porridges. There was significant contribution of calcium, potassium and iron in the product although zinc was low ranging from 0.4 to 0.89%. The results were compared with certified standard reference material (SRM) from literature and revealed that consumption of the sesame fortified porridges at suitable limit of quantification may satisfy the recommended daily dietary allowances of minerals and a good source of protein and energy.

Keywords: Cereals; Mineral composition; Porridge; Proximate composition; Sesame

4.1 Introduction

Grains in the form of sorghum, millet, or maize constitute a majority of daily sustenance and are sometimes referred to as staple foods. The proximate composition of all cereals is similar, yet each one has its special feature. While the five food substances (water, mineral matter (ash), protein, fat, and carbohydrate) are available in cereals, they occur in different quantities. Some cereals contain large quantities of protein while others practically have none. Some have considerable fat, while some have comparatively small quantities. However, the common characteristic of all cereals is that they contain a large amount of carbohydrate and a small amount of water (Omoniyi et al., 2018). Similarly, the proximate analysis for legumes follows its own trend where protein and fat are found high compared to carbohydrates and moisture. This study therefore aimed at determining the food composition of sorghum, pearl millet, groundnut and sesame as raw materials of sesame fortified porridge. The same analysis was done on the product to determine the net contribution of the individual raw materials in the final product. Standard methods by the Association of Analytical Chemist (AOAC) were adopted in the analysis (Horwitz & Latimer, 2005). The system consists of the analytical determinations of water (moisture), ash, crude fat (ether extract), crude protein and crude fibre. Protein was determined by Kjedhal analysis. Fat was determined by ether extraction using the Soxhlet extraction method. Ash was determined by ashing in a muffle furnace. Carbohydrate (Nitrogen-free extract (NFE)), representing sugars and starches in food, was calculated by difference. As for the mineral composition, Ca, Fe, and Zn in cereal samples were determined by flame Atomic Absorption Spectrophotometer (model AA-6701F) while K in the samples were determined by flame photometry.

4.2 Material and Methods

- Refer to **Chapter 3**, Subsection **(3.52 – 3.58)**

4.2.1 Research Design

A Completely Randomised Design was set up for the production of the different combinations of the fortified porridges. Several combinations were tried in the laboratory until six combinations were developed.

4.2.3 Data collection procedure

Triplicate and duplicate samples analysed during proximate analysis and data were recorded in an excel sheet and presented in tables and figures.

4.2.4 Data analysis procedure

An analysis of variance at 5% significance level was used to analyse the data which was managed by Statistical Package for Data Analysis (SPSS version 20).

4.2.5 Challenges encountered during data collection

While the ideal situation was to run all the samples in triplicate during the analysis, there were situations where due to limited resources only duplicate samples were run which limited the number of duplicated needed to compare the results. At times alternative chemicals different from the experiment procedure were used and such cases could contribute to variations in results obtained in this study.

4.3 Results and Discussion.

4.3.1 Formulation of the different fortified porridge combinations

The mixing ratios used were similar to the ones used by (Muhimbula, Issa-Zacharia, & Kinabo, 2011) with some modification. Six porridge mixes were formulated by mixing different ratios of staples and protein supplements and labelled as B1- B6. The ratios of mixing were calculated using the method described by (Muhimbula et al., 2011) where the ratio of inclusion for cereals was from 50% to 90% and that of legumes ranged from 10% to 30%. The following ratios were formulated (Sorghum: Pearl millet: Groundnut: Sesame) (**B1**) 60;0;20;20 (**B2**) 0;65;25;10 (**B3**) 60;20;15;5 **(B4)** 80;0;0;20 **(B5)** 0;70;0;30 **(B6)** 0; 75; 10;15 (6 treatment levels). These were compared to a traditional straight sorghum porridge used as control. The treatments were supplemented with sugar as energy supplements to improve the sensory attribute of the formulated foods and some salt. Each treatment of mixed composite flour was thoroughly mixed in order to achieve uniform mixture of legume flours with sorghum and pearl millet flour. The ingredients were mixed in Deluxe Blender (AE-099 model) at full speed for 5 minutes to obtain six different samples as shown in table 4.1 below;

Table 4.1 Blend formulations for the porridge

Main Ingredients	Formulation name	Mixing ratios (in grams)
Sorghum, groundnut, Sesame	B1	60g Sorghum + 20g Groundnut + 20g Sesame
Pearl Millet, groundnut, Sesame	B2	65g Pearl millet + 25g Groundnut + 10g Sesame
Sorghum, Pearl Millet, groundnut, Sesame	B3	60g Sorghum + 20g Pearl millet + 5g Groundnut + 15g Sesame
Sorghum, Sesame	B4	80g Sorghum + 20g Sesame
Pearl Millet, Sesame	B5	70g Pearl millet + 30g Sesame
Pearl Millet, Sorghum, groundnut, Sesame	B6	60g Pearl millet + 10g Sorghum + 15g Groundnut + 15g Sesame
Sorghum	Control	100g

KEY- Roasting times for groundnut and Sesame in the formulations

B1- Groundnut roasted at 70°C for 20min, Sesame roasted at 70°C for 20min

B2- Groundnut roasted at 70°C for 20min, Sesame roasted at 70°C for 20min

B3- Groundnut roasted at 70°C for 10 min, Sesame roasted at 70°C for 20min

B4- Sesame roasted at 70°C for 10min

B5- Sesame roasted at 70°C for 20min

B6- Groundnut roasted at 70°C for 10min, Sesame roasted at 70°C for 10min

The formulations were exposed to sensory evaluation and the most superior was then taken for proximate analysis.

Figure 4.1 Samples of the fortified porridge blends

4.3.2 Proximate composition of raw materials used in producing fortified porridge

Table 4.2 Results for proximate composition for raw materials

Sample	Ash (g/100g)	Moisture (g/100g)	Fat (g/100g)	Protein (g/100g)	Fibre (g/100g)	Carbohydrate (g/100g)
Groundnut	$4.6^{a} \pm 14.53$	$6.50^{a} \pm 0.05$	$40.50^{a} \pm 14.5$	$25.5^{a} \pm 0.99$	$9.95^{a} \pm 3.98$	$12.96^{a} \pm 0.85$
Pearlmillet	$38.89^{a} \pm 34.13$	$4.65^{b} \pm 0.50$	$12.00^{b} \pm 1.41$	$9.00^{b} \pm 0.14$	$5.65^{a} \pm 3.93$	$41.83^{b} \pm 1.12$
Sesame	$4.44^{a} \pm 1.39$	$3.57^{c} \pm 0.16$	$53.50^{a} \pm 2.12$	$18.8^{c} \pm 0.14$	$4.34^{a} \pm 1.71$	$4.64^{a} \pm 0.75$
Sorghum	$29.78^{a} \pm 22.99$	$7.53^{d} \pm 0.76$	$10.50^{b} \pm 1.41$	$8.55^{b} \pm 0.07$	$3.07^{a} \pm 0.44$	$40.57^{b} \pm 1.27$
P-value	0.31	≤0.001	0.01	≤0.001	0.24	0.01
F-value	1.40	134.84	15.88	524.06	2.07	16.23

Means having different superscripts within the column are significantly different at perent at p≤0.05

+- =Standard deviation of the sample mean is an estimate of how far the sample mean is likely to be far from population mean

Note: Comparison of proximate parameters is down the column

4.3.2.1 Moisture analysis for raw materials

All the samples had low moisture content of less than 12g/100g (see table 4.2). Sesame had the least amount of moisture (3.56g/100g) while the highest moisture was recorded in Sorghum sample (7.53g/100g). However, the results show that there was significant difference in moisture ($p<0.05$) across all samples of cereals and legume analysed. The moisture content of groundnut sample was significantly different to that of sesame ($p<0.05$) while the moisture content of sorghum was also significantly different ($P<0.05$) to that of pearl millet. The low moisture content in legumes (Table 4.2) could have been due to the high oil content of the seeds and the small size of the seed. Moisture content has important role in determining storage life of flour. The lower the moisture content, longer is storage stability (Kindiki, Onyango, & Kyalo, 2015). The moisture content of the raw material samples varied from 3.53-7.53%. The low moisture in the samples would enhance their shelf lives by preventing the growth of micro-organisms during storage.

4.3.2.2 Protein analysis for raw materials

The results show significant differences in the level of protein ($p<0.05$) between the legumes and the cereals from the samples of the raw material. However, there was also a significant difference between the protein content of groundnut (16.6g/100g) and sesame (18.8g/100g) ($p<0.05$). Groundnut had the highest crude protein followed by sesame (table 4.2). Pearl millet had the highest protein content of 9g/100g while sorghum had the least value of protein 8.5g/100g. However there was no significant difference ($p>0.05$) between the protein level contained in the cereals. The relatively high protein content of the groundnut and sesame as raw materials for the formulation of a fortified porridge gives enough evidence of the potential use of these raw materials on product formulation. The study shows that both sesame and groundnut are good sources of protein (validated by the nutrient composition) and this implies that consumption of porridge fortified with these legume crops improves the protein uptake by consumers. This result is highly expected for legume inclusion in feed formulation especially where protein is critical. Intra variations between the protein quantity between sesame and groundnut can be attributed to the variety of the crops, as well as other growth factors such as the type of soil, amount of rainfall and different climatic conditions.

4.3.2.3 Crude fibre analysis

Crude fibre was relatively low across all raw materials with the highest recorded for groundnuts at 9.95g/100g. Results show that there was no significant difference ($p<0.05$) between crude fibre of all the samples tested. Pearl millet had the highest figure of fibre (table 4.2) among the cereals while the legumes had groundnut with the highest fibre content (see table 4.2) and the lowest fibre content was found in the sorghum sample (3.07g/100g). The moderate fibre in the raw materials makes the ingredients suitable for easy colon digestion and also helps to reduce the risk of bowel cancer and gall stones when consumed. Fibre helps smooth peristalsis of digested food, keeps the digestive system health as well as stabilises glucose and cholesterol levels in the body. Temba et al., (2016) concluded that cereals have significant amounts of fibre and other minerals as compared to other crops, a result that was also found in this research. Fibre in cereals varied from 3.07 to 5.65g/100g while in legumes the range was from 4.34 to 9.95g/100g. Differences in results obtained in this study to those from literature may be attributed to the differences in the varieties, as well as growing conditions of the crops where they were obtained.

4.3.2.4 Fat analysis for the product

Results show that there was significant differences between the fat content of cereals and legumes ($p<0.05$). Among the cereals, pearl millet had the highest fat content (table 4.2) as compared to sorghum although there was no significant difference between the fat content of the two cereals. Significant difference ($p<0.05$) was found between the legumes (sesame and groundnut), with the highest amount of fat recorded in sesame (table 4.2). These results are in line with other findings from (Ogungbenle & Onoge, 2014) who also found out that sesame had a fat content ranging over 40% from the seed. Cereals (sorghum and pearl millet) recorded low values of fat in the analysis with pearl millet recording the highest fat content of 12.00g/100g against sorghum which had 10.5g/100g respectively. Fats are a important contributor to the energy value of foods as well as provide essential fatty acids needed for optimal neurological, immunological and functional developments in children (Ogungbenle & Onoge, 2014). The presence of fat based matrix in food is inhospitable to bacteria hence spread of food borne infection is avoided.

4.3.2.5 Carbohydrate analysis for raw materials

The results show that there was statistically significant difference ($p<0.05$) between the carbohydrate content of the cereals and the legumes. Cereals recorded the highest carbohydrate content with pearl millet having 41.83g/100g followed by sorghum which recorded 40.57g/100g sample. Legumes scored lower values of carbohydrate per g/100g sample. However results between the cereals (sorghum and pearl millet), indicated that there was no statistically significant difference ($p<0.05$) in the amounts of carbohydrate content between the two samples. Similar results were obtained for the legumes (table 4.2). There was no significant difference ($p<0.05$) between the carbohydrate content found in groundnut and sesame samples. These results although they recorded lower than those reported by Durojaiye, Drambi and Chukwu, (2016), 65 – 75% of carbohydrate in sorghum, were not very far from other scholars' findings. Legumes had relatively low carbohydrate content about 4.64% an attribute that is common with all legume crops. Bamigboye et al., (2010) recorded about (21.4 ± 0.12) carbohydrate in whole seed sesame, a value different from what was found in this research. Oyerinde, (2017) recorded 15.2% carbohydrate while Temba et al., (2016) recorded 19% in a sample of groundnut. These research findings were found not different from what was obtained in this research where the groundnut sample recorded 12.95%. Rehman et al., (2016), revealed that cereals are rich in carbohydrate and low in protein. Muhimbula et al., (2011) also concluded with similar results that millets contain more carbohydrate than protein.

4.3.2.6 Ash analysis for raw materials

Results from the analysis showed that there was no significant difference ($p<0.05$) in the ash content of the raw materials analysed. However, the highest ash content was recorded in the sorghum sample which had 38.89g/100g and the lowest recorded in sesame 4.44g/100g. Obtained results showed that cereals had higher amount of ash as compared to the legume samples. The ash content for legumes ranged from 4.44% sesame to 17.99% in groundnuts. The value for ash obtained in sesame is comparable to the value of 6.5 ± 0.05 reported by Bamigboye et al., (2010), while the values for ash in groundnuts was higher than findings by Temba et al., (2016) who recorded only 2% ash content in a groundnut sample. The ash content gives an overall estimate of the total mineral elements present in the food. Ash is a non-organic compound continuing mineral contents in the food and nutritionally aid in the metabolism of the organic compounds such as fat and carbohydrate. Essential valuable and useful minerals needed by the body for development are found in ash.

4.3.3 Proximate mineral composition of raw materials used in formulating fortified porridge

Table 4.3 Proximate analysis for minerals in raw materials

Sample	Potassium(mg/100g)	Zinc(mg/100g)	Iron(mg/100g)	Calcium(mg/100g)
Groundnut	$174.10^{a} \pm 24.56$	$3.24^{a} \pm 0.82$	$4.47^{a} \pm 0.51$	$7.84^{a} \pm 0.04$
Pearl millet	$159.83^{a} \pm 5.20$	$4.39^{a} \pm 0.14$	$6.38^{a} \pm 2.33$	$4.81^{b} \pm 0.59$
Sesame	$149.69^{a} \pm 19.73$	$4.34^{a} \pm 0.76$	$8.05^{a} \pm 1.07$	$221.07^{a} \pm 27.84$
Sorghum	$153.60^{a} \pm 6.53$	$2.35^{b} \pm 0.96$	$5.19^{a} \pm 0.01$	$4.48^{b} \pm 0.02$
P-value	0.013	0.029	0.168	≤0.001
F-value	13.98	5.12	169.7	

Means having different superscripts within the column are significantly different at p<0.05

+- =Standard deviation of the sample mean is an estimate of how far the sample mean is likely to be far from population mean.

Note: Comparison of proximate parameters is down the column

4.3.3.1 Analysis of potassium in raw materials

Results from the analysis showed that there was significant difference ($p<0.05$) across all the samples for potassium. The sample with the highest amount of potassium was the groundnut sample (174mg/100g) and the least amount (149.69g/100g) was found in sesame. As compared to findings by Bamigboye et al., (2010), the levels of potassium in sesame sample was well within the range (149.69mg/100g in sample vs 106.7 mg/100g) found in raw sesame. Potassium helps maintain fluid balance, and high intake improves blood pressure, according to the American Heart Association (Omoniyi et al., 2018). The analysed samples showed relatively high levels of potassium ranging from 149.69 to 174.10 mg/100g for the legumes and 153.60 to 159.83 mg/100g for the cereal samples. There was significant difference ($p<0.05$) in the level of potassium across the samples. Potassium level in cereals was lower than levels found by Omoniyi & Abdulrahman, (2018) whose levels of potassium in their research ranged between 366.67% for pearl millet and 400.00% for sorghum. Differences in the research findings and those from literature can be attributed to different varieties used in the research as well as different climatic conditions of the growing areas of the crops from which they were collected. Potassium in sesame was high (149.69mg/100g). These findings were similar to the findings by (Bamigboye et al., 2010) who also found similar values for potassium in raw whole grain sesame to be 106.7 ± 0.50mg/100g. This research finding was higher than that of the other researchers. Potassium plays pivotal in osmoregulation and hence is an important micro- nutrient that can be added to formulate diets. Its availability in raw materials is a good indicator of it potential availability in formulated composite porridge blends. The high potassium level in sesame also justifies its inclusion in fortifying cereal based diets for the fight of micro nutrient deficiencies.

4.3.3.2 Analysis of Zinc in raw materials

Results from the analysis showed that there was no significant difference on the amount of zinc contained in three samples of groundnut, pearl millet and sesame ($p>0.05$). However, the only significant difference ($p<0.05$) in the amount of zinc among the samples was noted in the sorghum sample which recorded (2.35mg/100g). With regards to sesame, the amount of zinc found in the sample analysed were not different to the ones obtained by (Bamigboye et al., 2010) who recorded 4.46mg/100g in raw sesame although while the sample had 4.34mg/100g. Zinc is considered as one of the most essential mineral elements in foetal, infant and early childhood development. Unavailability of this micro nutrient leads to poor growth and development. The raw samples, showed presence of zinc which is an essential micronutrient that could be contributed in the final product.

4.3.3.3 Analysis of Iron in raw materials

Result from the analysis showed that there was statistical difference ($p<0.05$) between the mean amounts of iron in the samples of raw materials analysed. Sesame had the highest amount of iron (8.05mg/100g) across all the samples analysed. Pearl millet had significantly high amount of iron (6.38mg/100g) among the cereals, although the value was lower than that of sesame. The groundnut sample had the lowest amount of iron per 100g. The research findings however were slightly different from Bamigboye et al., (2010) who recorded 3.83 ± 0.75 of iron in a sample of raw sesame. All samples however, had significant amounts of iron recorded and sesame contributed the highest amount of this micro nutrient, this justifies the inclusion of sesame in formulation of complementary diets for both children and adults especially for the health benefits of iron supplementation.

4.3.3.4 Analysis of Calcium in raw materials

Results of the analysis show sesame had the highest amount of calcium from the analysis (221mg/100g). The figure was outstanding compared to the values obtained from the other samples. However, the analysis showed that there was significant difference ($p<0.05$) between the calcium levels of cereals versus the legumes. Legumes had a higher amount of calcium especially sesame. The findings in this study were similar to findings done by Bamigboye et al., (2010) who recorded (281.1 ± 0.68) calcium level in raw sesame. The raw materials proved to contain significant amounts of calcium and if used in formulation of porridge there is potential to harness this mineral into the final product. Nedumaran *et al.*, (2015) also concluded that legumes play a vital role as sources of micro nutrients such as, calcium, iron, phosphorus and other minerals

4.4 Proximate macro nutrient analysis of the product

Table 4.4 Comparative macro nutrient analysis of the different porridge blends in comparison to the raw materials

Porridge Blend	Moisture (g/100g)	Ash (g/100g)	Fat (g/100g)	Protein (g/100g)	Fibre (g/100g)	Carbohydrate (g/100g)
B1	$4.90^{a} \pm 0.14$	$3.28^{a} \pm 0.39$	$45.5^{a} \pm 2.12$	$19.69^{a} \pm 0.08$	$2.13^{a} \pm 0.14$	$24.53^{a} \pm 0.01$
B2	$3.95^{b} \pm 0.71$	$2.71^{b} \pm 0.04$	$41.0^{b} \pm 1.41$	$19.34^{a} \pm 0.04$	$1.58^{a} \pm 0.02$	$31.42^{a} \pm 0.01$
B3	$5.70^{c} \pm 0.14$	$5.37^{c} \pm 3.00$	$35.0^{a} \pm 1.41$	$14.72^{a} \pm 0.05$	$2.73^{a} \pm 0.01$	$36.84^{a} \pm 0.00$
B4	$6.15^{b} \pm 0.35$	$3.13^{d} \pm 0.17$	$36.0^{c} \pm 1.41$	$15.47^{a} \pm 0.13$	$3.62^{a} \pm 0.02$	$35.63^{a} \pm 0.01$
B5	$4.10^{d} \pm 0.14$	$3.47^{e} \pm 0.03$	$49.5^{d} \pm 2.12$	$20.12^{a} \pm 0.08$	$2.10^{a} \pm 0.01$	$20.71^{a} \pm 0.01$
B6	$4.40^{e} \pm 0.21$	$3.12^{f} \pm 0.17$	$49.5^{e} \pm 10.61$	$18.69^{a} \pm 0.08$	$2.34^{a} \pm 0.07$	$21.95^{a} \pm 0.01$
Control	$7.15^{c} \pm 0.21$	$2.37^{g} \pm 0.17$	$34.0^{a} \pm 2.83$	$8.55^{b} \pm 0.07$	$6.24^{a} \pm 0.01$	$41.69^{b} \pm 0.01$
P value	≤ 0.001	0.33	0.03	≤ 0.001	≤ 0.001	≤ 0.001

Means having different superscripts within the column are significantly different at p<0.05

+- =Standard deviation of the sample mean is an estimate of how far the sample mean is likely to be far from population mean

Note: Comparison of proximate parameters is down the column

4.4.1 Moisture content analysis for formulated porridge blends.

Results show significant differences in moisture ($p<0.05$) content across all the porridge blends B1 to B6 as shown in table 4.4. However, between samples B2 and B4 and also on B3 and control there were no significant differences ($p<0.05$) in moisture. All the formulated samples had lower moisture content as compared to the control (100% sorghum flour) ranging from 3.95% (B2) to 6.15% (B4) an indication of good storage attributes to the formulated fortified porridges. Results also show noted differences in moisture content between the raw samples and the formulated porridge blends. Raw materials had a higher moisture content ranging from 3.57g/100g to 7.53g/100g across the samples which was slightly higher than that of the formulated porridge blends. The roasting done during product formulation could have resulted in the lower moisture content of the product. Low moisture content of food samples is a desirable phenomenon, since the microbial activity is reduced. Low moisture in food samples has the advantage of increasing the shelf life of food products. Roasting cereal grains and legumes seeds at 70 Degrees Celsius at varying times, contributed to the loss in moisture (reduced water activity) of the flours produced after milling. Similar results were obtained by Sampath, (2015) who concluded that roasting improves colour, extends shelf life, enhances flavour and reduces anti-nutritional factors of cereals and legumes.

4.4.2 Ash analysis for the product

Results from the analysis showed that there was high significant difference ($p<0.05$) between the ash content of the porridge blends (B1-B6). The highest ash content was found in blend B3 (5.37g/100g) and the least ash content was in the control which had 2.37g/100g. The results show low ash content among the formulated blends as compared to the raw samples which was different from the results by Sampath, (2015) who found out that the ash content of raw and roasted maize flours was 1.23% and 1.51% respectively. Roasting of the grains decreased the ash content of the flour products as compared to the raw materials. Raw sorghum and pearl millet had ash content of 29.78% and 38.89% respectively before processing whereas the ash content of the porridge products was found lower. These findings were similar to the findings by Sampath, (2015) who concluded that roasting and germination significantly affect ash, fat, fibre, carbohydrate and energy content of a product. However, the availability of this mineral in the final product is an indication of the contribution of the raw materials used in product formulation.

4.4.3 Fat analysis for the product

All the samples analysed showed a relatively high level of fat (35% - 49.5%) as shown in table 4.3. However, there were statistically significant differences ($p<0.05$) on fat content for the samples analysed. Samples B1 and B3 showed no significant differences ($p>0.05$) between the fat content of the samples, but however, the two samples were significantly different ($p<0.05$) from the rest of other samples (B2, B4, B5 and B6) in oil content. The formulated porridge product samples had significantly higher levels of fat across all the analysed samples as compared to the raw samples. The high fat content in legumes could have raised the oil content of the formulated porridge products. Sample B5 and B6 had the highest fat content of 49.5%, while B3 had the lowest fat content of 35%. The control sample had even a lower fat content as compared to all the other product samples (table 4.3) a result that justifies use of legumes in value addition as well as fortification of cereal flours. In the raw materials legumes had the highest fat content and this could have been the source of fat in the product. Roasting also could have contributed to the increased fat content of the formulated porridge blends. The increase in fat can be attributed to the increased activity of lipolytic enzymes which produced more free fatty acids during the process of roasting (Chukwuma et al., 2016). Fat plays an important role in diets as it contributes to flavour and mouth feel of the product (Chukwuma et al., 2016).

4.4.4 Fibre analysis for the product

Results from the analysis showed that there was significant difference ($p<0.05$) in the amount of fibre in the formulated porridge blends and the control (100% sorghum flour). However, the control flour had the highest fibre (6.24%), while among the porridge flours, blend B2 had the lowest fibre percentage (1.58%). Blend B4 had a relatively high fibre percentage (3.62%) as compared to the other blends. The samples showed an overall low fibre content ranging from 1.58% to 6,24% an indication similar to findings by (Solomon, 2005) who concluded that compounded diets of cereal and legumes had fibre content of less than 10%. Compared to the raw materials, fibre content of the product was relatively lower than that of raw materials. Fibre in the raw materials ranged from 3.07 – 9.95% while fibre in the formulated product ranged from 1.58 – 6.24%. Roasting could have had an effect of reducing the fibre content of the final product thus giving low values of fibre in the product than in raw materials. Raw samples had significantly higher fibre (3.07-9.95%) whereas the final product had a maximum of 3.62% fibre in sample B4. The findings were similar to research findings by (Ezeokeke & Onuoha, 2016) who recorded similar quantities of fibre in a cereal and legume flour blend although (Solomon, 2005) recorded different findings from this research and concluded that roasting actually increases the fibre content of a product. The difference in the result could be a function of the processing method (excessive heat during roasting in the oven) as temperature was being controlled with a non-fixed thermometer.

4.4.5 Protein analysis for the product

Protein content of processed samples varied between 14.72± 0.05% and 20.12±0.08. Blend B5 had the highest protein content followed by B6. Blend B3 had the lowest protein content among the samples analysed. No significant differences ($p<0.05$) in the mean protein content of the formulated blends was recorded. The control sample had the lowest protein content of $8.55^{b} \pm 0.07$ and the finding was significantly different from the rest of the formulated blends. The results show significant contribution of the legumes in improving the protein content of the formulated porridge blends based on the fact that the protein content of the product was higher than that of the two cereals. Roasting could have had an effect in improving the quality and amount of protein in the product. These findings are in line with by (Sampath, 2015) who concluded that the nutritional value of native proteins is improved by heat treatments as they are converted to more digestive denatured forms. The findings justify the inclusion of legumes especially sesame in formulation of complementary diets as they are significant sources of protein. Protein energy malnutrition (PEM) is a public health problem in many developing countries. PEM is a huge burden, as it is associated with poor health and physical functioning (Temba et al., 2016). PEM manifests in various forms such kwashiorkor, marasmus and also associated with comorbidities such as tuberculosis, anaemia, malaria and diarrhoea (Temba et al., 2016) and equally considered a risk factor for death. Mixing readily available cereal and legume crops for food production, therefore can effectively augment the intake of an affordable and more nutritionally balanced protein source which alleviates prevalence of PEM in many African countries, where malnutrition remains a serious threat. Sesame therefore proved its ability to be included in formulation of composite porridges due to its high protein, fat as well as mineral composition which are attributes that are beneficial to the fighting micro nutrient malnutrition.

4.4.6 Carbohydrate analysis

Most carbohydrates come from grain products, tubers, roots and fruits, are the main source of energy in the diet. The cereal- legume based diets were found contain carbohydrate in the range of 20.71-36.84%. It is critical when formulating diets for children and infants, to make sure that the ratio of carbohydrate to fat and protein is taken into consideration. High protein and low carbohydrate diet results in a scenario where amino acids of the protein will be diverted to glucose synthesis and the body is deprived of protein meant for body building with resultant wasting and stunting. Values obtained in this study seem to suggest that carbohydrate will not be sufficient to meet requirements but there is also high level of fat in the product and this can supplement the low carbohydrate in the product. Although there is no fixed recommended daily allowance for carbohydrate intake, recommendations from WHO and FAO suggest an intake of about 50g per day as being sufficient to meet energy needs for children.

4.5 Proximate minerals composition of the product

Table 4.5 Micro nutrient analysis of the different porridge blends in comparison to the raw materials

Porridge Blend	Potassium (mg/100g)	Zinc (mg/100g)	Iron (mg/100g)	Calcium (mg/100g)
B1	13.06^{a} ±0.00	0.65^{a} ±0.07	6.30^{a} ±0.07	11.79^{a} ±0.02
B2	11.50^{b} ±0.01	0.62^{a} ±0.01	7.43^{a} ±0.01	6.91^{a} ±0.02
B3	12.74^{a} ±0.02	0.59^{a} ±0.07	5.48^{a} ±0.01	8.98^{a} ±0.01
B4	14.17^{a} ±0.00	0.40^{b} ±0.11	4.72^{a} ±0.04	8.47^{a} ±0.07
B5	83.56^{a} ±0.25	0.79^{a} ±0.11	8.79^{a} ±0.04	10.85^{a} ±0.05
B6	12.31^{a} ±0.00	0.89^{c} ±0.04	7.02^{a} ±0.03	7.69^{a} ±0.04
Control	81.96^{a} ±0.32	0.63^{a} ±0.01	6.45^{a} ±0.03	2.78^{a} ±0.01
P value	≤0.001	≤0.004	≤0.001	≤0.001

Means having different superscripts within the column are significantly different at ($p<0.05$).

+- =Standard deviation of the sample mean is an estimate of how far the sample mean is likely to be far from population mean.

Note: Comparison of proximate parameters is down the column

Results from the analysis (table 4.5) above show that there was significant contribution of Ca, Fe, Zn and K in the formulated porridge blends. Notable quantities of potassium, iron and calcium were found in the formulated porridge samples compared to the control (100% sorghum flour). Results show that significant amounts of potassium of up to 83.56% in blend B5 were harnessed in the product while the other blends ranged between 11 and 13%. Zinc was low (0.4-0.89%) in the product as compared to the raw materials. The lower values for zinc in the product could have been due to some loss of the mineral during processing of the flours. Iron and calcium were found in better concentrations (4.72 – 8.79mg/100g) in the final product than in the raw materials. Sesame which had high concentrations Ca and Fe in the raw materials could have been the source of the minerals in the final product. The results show that the inclusion of sesame and groundnuts in formulating the fortified porridge blends had a significant impact in boosting the availability of micro nutrients in the final product. Iron and calcium are important micronutrients that are of significant importance in fighting micro nutrition hence their availability in a formulated blend is crucial in fighting micro nutrient problems.

4.6 Conclusion

Empirical evidence from the study proves that legumes such as sesame and groundnuts contain high levels of proteins, fats and micronutrients as compared to isolated cereals (pearl millet and sorghum). Similarly, cereals dominated in carbohydrate levels as evidenced by values of over 40% in both sorghum and pearl millet. This result is similar to findings by others researchers who also observed similar trends in protein and carbohydrate levels between legumes and cereals. Analysis of micro nutrients in legumes also supported the stated hypothesis that legumes are rich in micronutrients as compared to cereals. Results from table 4.2 show that potassium, iron zinc and calcium were high in legumes especially in sesame. Cereals were dominant in potassium although overall legumes showed significant high quantities of the micro nutrients compared to cereals.

Formulated porridge products were generally lower in micronutrients as compared to the isolated legume and cereals. Potassium was low in the porridge blends as compared to the control while calcium, iron and zinc were higher in the porridge blends than in the raw materials. The loss in concentration of micronutrients in the product could be a result of the processing method used. Despite the lower values of micro nutrients in the formulated porridge blends, the amounts present were found within the recommended daily allowance for consumption as defined by the standard minimum requirements in diets. Results therefore, prove that there was a balance of micro nutrients between cereals with generally lower quantities of micronutrients and legumes with comparatively higher quantities of micro nutrients. The processing procedure could have been a reason for low values for micronutrients in the formulated porridge blends. Roasting has a significant impact on the ash content of a product hence reduces amount of micronutrients in the product as compared to raw samples. However, the quantities of micronutrients as evidenced by this research indicate that sesame is a rich crop in both macro and micro nutrients hence a good source of fortifying low micro nutrient cereal based diets. Results from this study help conclude that it is possible to use local household food sources to formulate multi mixes that can be used as home-based complementary foods with a balance of micro nutrients. The blends formulations in this study can therefore be recommended for use particularly by rural and poor mothers to feed their infants and children during the complementary feeding period.

4.7 Recommendations

The current study analysed the nutrient composition of the raw materials as well as the product made from sorghum, pearl millet, groundnut and sesame. Of particular importance was sesame crop as a potential source of both macro and micro nutrients. Results of the study indicated that the crop is rich with both macro (protein and fat) and micro nutrients (Ca, K, Fe and Zn). Based on the findings from this study, use of legumes such as sesame can be recommended in formulating composite cereal and legume porridges. There is potential in harnessing the abundant nutrients in the crop especially in food products made out the sesame crop. Groundnut has been a traditional source of protein as well as other minerals among smallholder farming set ups, however, this study recommends sesame as an alternative source of these micro nutrients when formulating complementary porridges. Sesame thrives well in semi-arid regions and its drought tolerant, these attributes can be advantages to farmers who are in semi-arid regions to grow the sesame and as well benefit from the nutritional richness of the crop. The use of locally available foods in the right combination as a substitute for the expensive commercial complementary food is therefore recommended as they are cheap readily available and nutritious.

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CHAPTER 5 Results

Evaluation of sensory properties for fortified porridge blends made from sorghum, pearl millet, groundnuts and sesame.

Abstract

Composite flours were formulated by fortification of the sorghum and pearl millet flour with groundnuts and sesame flours to prepare a complimentary porridge. For this purpose, groundnut and sesame were supplemented at 5, 10, 15, 20, 25, and 30% levels to formulate variant compositions. Afterwards, the porridge flours were prepared and analysed for sensory attributes of texture, flavour, taste, appearance and their overall acceptability by end-users. A total of 100 semi trained university students in the Department of Food and Family Sciences at the University of Zimbabwe were subjected to the sensory evaluation of the formulated porridges. Results of the analysis showed that blend B3 had the highest acceptability, followed by blend B1 and B6 according to the rank of liking by the panellists. All the formulated porridges scored above 50% in overall acceptability while the control (100% sorghum) scored below 50%. Data from sensory evaluation done on all the porridge blends were analysed using the Kruskal-Wallis H test which showed that there was a statistically significant difference in taste, flavour, appearance and texture between the different porridge formulations with the following results: χ^2 (6) = 86.271, p = 0.001 for appearance, χ^2 (6) = 146.86, p = 0.001 for taste, χ2 (6) = 221.06, p = 0.001 for flavour, and χ^2 (6) = 101.76, p = 0.001 for texture. A post Hoc LSD test for the mean scores between the formulations revealed that for appearance blend B2, B4 and the control were significantly different ($p<0.05$) from the other blend. For taste, B2 was significantly different ($p<0.05$) than all other blends. Blend B2, B4, B5 and B6 were significantly different in flavour from the rest of the other blends. B2, B3 and B4 were significantly different from the rest of the blends on texture.

Key words: Cereals, Composite flour, Sensory attributes, Sesame,

5.1 Introduction

According to Omoba, Taylor, & de Kock, (2015) increasing numbers of people in Africa continue to suffer from malnutrition caused by inadequate intake of both macro and micro nutrients. It is during complementary feeding when many children face the risk of malnutrition and it is important to ensure that they are fed properly with nutritious and safe foods (WHO, 2006). However, well-formulated complementary foods in the Zimbabwean market are not affordable to mothers in most resource-poor communities. Supplementation of cereals based porridges with locally available legumes rich in protein and lysine, has the potential to increase protein content of cereals and ultimately their protein quality through mutual complementation of their individual amino acids. The use of local foods formulated in the home and guided by the principles of high nutritional value, acceptability, low price, and use of local food items is therefore critical in achieving the goals of micro nutrient deficiencies. This study therefore, formulated and assessed the sensory attributes of six formulated porridges made from locally, cheap and available sources of cereals and legumes. Sesame was assessed for its inclusion in formulation of cheap and affordable composite porridges for use by resource poor communities.

Sensory attributes of taste, flavour, appearance and texture were assessed including the general acceptance of the porridges by the judging panellist.

5.2 Material and Methods

Refer to chapter 3 subsection 3.4.4, 3.4.5 and 3.6

5.2.2 Sampling procedure

One hundred, level 2 and level 4 University of Zimbabwe students doing Food and Family Sciences were selected at random during the time when they were doing practical for sensory evaluation and these participated in the sensory evaluation of the formulated porridges.

5.2.3 Data collection procedure

A questionnaire was used to collect data for sensory evaluation. A drafted questionnaire where panellists were supposed to fill in their scores according to a 9 point hedonic scale provided (see Appendix 1) was the tool for data collection. Panellist were also asked to score the formulated porridges against a score of 1-6 according to their liking of the porridges where 1 – meant liked most and 6 – meant least liked as a quick assessment of acceptability of the formulated porridges.

5.2.4 Data analysis procedure

For sensory evaluation, quality parameters, Kruskal-Wallis non-parametric One Way ANOVA test was used to allow comparison of the independent treatments and means were separated using the LSD test. Results were presented in the form of tables, graphs and pictures Christensen *et al.,* (2015).

5.2.5 Challenges encountered during data collection

Proper recording of sensory data by panellist was a challenge during questionnaire completion in data collection. One panellist had to evaluate six different porridges and this created problems as the panellist tried to score each of the attributes for the six porridge blends.

5.3 Results and Discussion

Descriptive sensory analysis is a standard tool that gives comprehensive insight on the nature and size (quantity or intensity) of sensory attributes as perceived by humans while consuming food products (Omoba et al., 2015). The product profiling information gathered in understanding the effects of ingredients on sensory properties of products is useful for predicting potential consumer responses to new products. In this study the effect of various inclusion levels of groundnut and sesame on sorghum and pearl millet flours was investigated.

5.3.1 General acceptability of the porridge blends

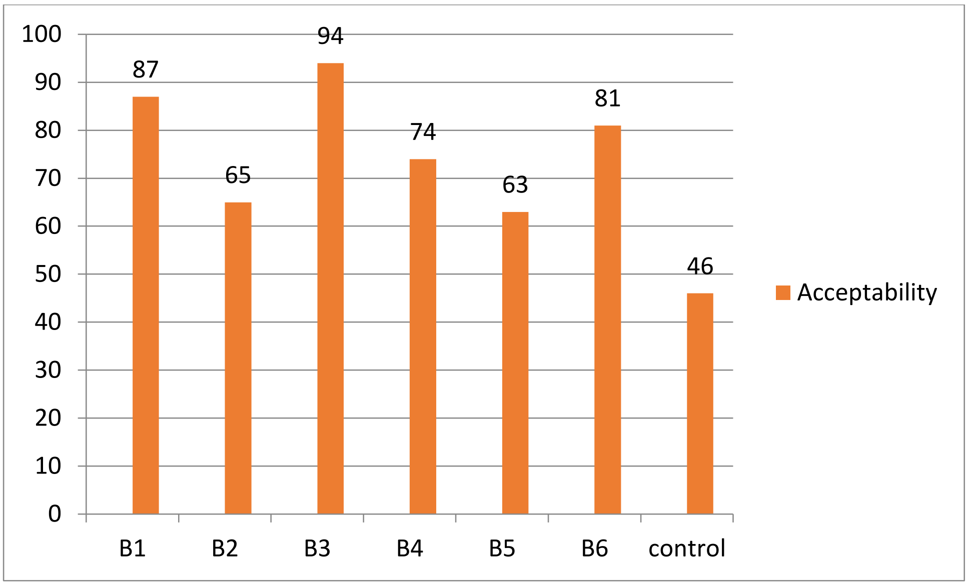

Figure 6: Overall acceptability of the porridge blends from simple ranking

Key = (**B1**) 60;0;20;20 (**B2**) 0;65;25;10 (**B3**) 60;20;15;5 **(B4)** 80;0;0;20 **(B5)** 0;70;0;30 **(B6)** 0; 75; 10;15

***B1**- Groundnut roasted at 70^oC for 20min, Sesame roasted at 70^oC for 20min*

***B2**- Groundnut roasted at 70^oC for 20min, Sesame roasted at 70^oC for 20min*

***B3**- Groundnut roasted at 70^oC for 10 min, Sesame roasted at 70^oC for 20min*

***B4**- Sesame roasted at 70^oC for 10min*

***B5**- Sesame roasted at 70^oC for 20min*

***B6**- Groundnut roasted at 70^oC for 10min, Sesame roasted at 70^oC for 10min*

Generally, formulated porridges B3, B1 and B6 were highly acceptable upon ranking by the panellist. (94%, 87% and 81% for semi trained panellists, respectively). The acceptability levels were significantly higher than the rest of samples. Differences in acceptability could have been a function of the processing procedure. Roasting could have significantly improved the organoleptic preferences of the formulated porridges improving the colour, taste, aroma, texture and general acceptability which is important for increasing food intake. The caramel flavour produced during the roasting of cereals, the nutty flavour produced from the roasting of groundnut and sesame, sugar and some salt all contributed to the flavour and taste of the porridge blends which was not found in the control (100% sorghum flour-46% acceptability). The six blends however, scored above 50% during rating for acceptability indicating that the formulated mixes were on average appealing. The latter processing procedures therefore helped obtain various objectives of palatability, nutrition and food consumption.

5.3.2 Sensory evaluation for attributes of taste, flavour, appearance and texture of porridges made from different formulations as tested by semi-trained panellists

Table 5.1: Sensory evaluation of formulated porridges

Blend name	Taste	Flavour	Appearance	Texture
B1	319.14	325.56	339.11	294.14
B2	350.00	355.83	346.31	296.31
B3	402.07	530.45	458.82	306.19
B4	466.89	390.22	261.94	270.69
B5	377.89	385.04	394.36	435.88
B6	384.45	339.64	402.39	366.14
Control	153.04	123.02	250.56	484.13
P value	<0.001	<0.001	<0.001	<0.001

**mean ranks for Kruskal-Wallis one-way analysis of variance*

Sensory evaluation analysis done on all the porridge blends using the Kruskal-Wallis H test showed that there was a statistically significant difference in taste, flavour, appearance and texture between the different porridge formulations. χ^2 (6) = 86.271, p = 0.001 for appearance, χ^2 (6) = 146.86, p = 0.001 for taste, χ2 (6) = 221.06, p = 0.001 for flavour, and χ^2 (6) = 101.76, p = 0.001 for texture. The mean ranks for the different formulations are shown in table 5.1 above. The highest mean rank for taste was noted on Blend 4 followed by B3 with the least in terms of taste being the control. Blend B3 scored highest on flavour followed by B4 with the lowest mean rank found on B1. The control had the lowest mean rank on flavour. Appearance was highest on B6 while texture was highest on blend B5. A post Hoc LSD test for the mean scores between the formulations revealed that for appearance blend B2, B4 and the control were significantly different (p<0.05) from the other blends. In terms of taste, B2 was significantly different (p<0.05) from all other blends. Blend B2, B4, B5 and B6 were significantly different in flavour from the rest of the other blends. B2, B3 and B4 were significantly different from the rest of the blends in texture.

5.4 Conclusion

All the formulated porridge blends were liked by panellist as shown by the high acceptability scores (above 50%) as compared to the consumption of isolated consumption of cereals only which is the most common practice among small holder farmers. Sensory attributes analysis revealed that all the formulated porridge blends mixes scored high in terms of taste, flavour, appearance and texture and were significantly different in taste and flavour with the control sample (100% sorghum porridge) which was a good indicator of the inclusion of legumes (sesame/groundnut) in the formulation. The results therefore help conclude that different combinations of the porridge had a significant impact on improving the sensory attributes of the porridges as compared to the isolated consumption of cereal porridge. Blend B3 (60g Sorghum + 20g Pearl millet + 5g Groundnut + 15g Sesame) which scored high on taste, flavour and appearance would be a favourable combination for consumers. Roasting the legumes at both 10 minutes and 20 minutes could have improved the organoleptic qualities of the cereals – legume porridge combinations and produced some pleasant flavours that resulted in high acceptability and different sensory attributes recorded for the formulated porridges. There is evidence from this research that helps conclude that legumes such as sesame can be used in value addition and fortification of cereal flours without compromising the sensory attributes of the consumers.

5.5 Recommendations

Based on the findings from this research, sesame can be recommended for the formulation of fortified porridges. Sensory evaluation revealed that all the porridge mixes that had an inclusion of sesame roasted at 10 and 20 minutes improved the acceptability of the porridges formulated (>50% acceptability). Blend B3 would be recommended as a special formulation for production of a highly nutritious and micro nutrient balanced complementary porridge for smallholder farmers. The fact that there were no negative effects to the sensory attributes of the consumers caused by addition of sesame in the formulations, provide good recommendation for sesame to be an alternative crop especially among smallholder farmers in improving the nutritive value of cereal based porridges without compromising availability of critical nutrients especially macro and micro nutrients.

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CHAPTER 6
SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

6.1 Introduction

This chapter gives a research summary, conclusions and recommendations to the study as well as discussion on some policy implications. Areas for further research are also outlined in this chapter.

6.2 Research summary

Micronutrient malnutrition remains a public health threat in most developed and developing countries. Effects of micronutrient malnutrition manifest in various forms but sometimes result in negative effects to human health and development and at times lead to death. Smallholder farmers grow and eat some the crops that are rich in micro nutrients but the problem is there is lack of dietary diversity. Most rural diets are starch based and therefore lack some of the important contribution by legume crops in terms of micro nutrients. Smallholder farmers lack of information on how to utilise both cereals and legumes for the benefit of improved micronutrient consumption. This study therefore focused on analysing the role played by groundnuts and sesame as potential supplements for micro nutrients in complementary porridges. Nutrient composition of raw materials (sorghum, pearl millet, groundnut and sesame were analysed and these were compared with the nutrient composition of the product. This was done to assess the overall contribution of raw materials in improving the quantities of micronutrients in the complementary porridges. The study further assessed the sensory attributes of the formulated diets. This was done to assess whether there was any significant effect on taste, flavour, appearance and texture among the formulated combinations. Sensory evaluation is a key assessment in the development of a food product as it determines acceptability of the food product by the consumers. Quadrant 1 and 3 of the conceptual framework in chapter 2 are concerned with household all year round accessibility of food as key in attaining individual nutritional health status. This study therefore worked on value addition and fortification of cereal grains with legume crops as a strategy for improved nutrition to individuals.

6.3 Conclusions

The groundnut and sesame fortified porridge formulations in the present study were formulated from locally available low-cost food materials commonly grown and consumed in smallholder farming areas of Zimbabwe. The mixing ratios constituted formulations that had enough protein to meet the protein requirements for both children and adults as recommended for complementary feed (14 – 20% protein). Notable micro nutrient levels for calcium, iron and potassium were observed in the product which was an indication of the contribution of the legumes especially sesame in improving the micro nutrient levels of the cereal based diets. There was significant difference in the macro and micro nutrient analysis of the product compared to the raw cereal flours, a sign that helps conclude the nutritional richness of legumes in protein and fat as well as minerals. It can be concluded that the formulated food mixes are potentially suitable for use as complementary foods especially in the view of fighting micronutrient malnutrition and also in the view that commercially produced complementary foods are expensive and go beyond the reach of many smallholder farming communities of Zimbabwe.

While sesame is grown as a cash crop by smallholder farmers in districts like Buhera and Mt Darwin, this study concluded that sesame is a good source of both macro (protein and fat) and micro nutrients (iron, zinc, calcium and potassium) and farmers in the smallholder farming set ups can benefit from this crop through value addition and fortification of cereal based porridges. Utilisation of sesame crop can therefore be improved by including crop in formulating locally cheap and highly nutritious complementary porridges.

The nutty flavour produced from roasting groundnuts and sesame as well as the caramel flavour from the roasting of cereals contributed much to the appeal as well as flavour of the formulated porridge blends. Blend B3 (Groundnut roasted at 70^{o}C for 10 min, Sesame roasted at 70^{o}C for 20min) which had the highest acceptance followed by B1 (Groundnut roasted at 70^{o}C for 20min, Sesame roasted at 70^{o}C for 20min) could be potential formulations for consideration by smallholder farmers. Roasting had a significant impact on the acceptability of the formulated porridge blends as well as on the nutritional composition of formulated porridge flours. Sensory evaluation of the formulated porridge blends concluded that notable differences in sensory attributes were on the control (100% cereal) while there were no significant differences in the taste, appearance, flavour and texture between the six formulated porridges.

6.4 Recommendations

Evidence from this study show that nutritious, acceptable and affordable complementary foods can be formulated using locally available or household food items, and can be better options compared to use of straight cereal based porridges especially by smallholder farmers. Cereal – legume flours have great nutritional values which could be harnessed by processing methods to meet nutritional needs of children who are the most vulnerable to micro nutrient malnutrition. Based on the findings from this research, crops like sesame, although neglected can be recommended for inclusion in formulation of nutritious healthy porridges. Instead of depending on cereal based diets for complementary feeding, farmers can make use of cereal – legume combinations produced from this study to improve the quality of complementary feeds given to their children. The formulated blends were found to be meeting requirements in some micronutrients notably Fe, Zn and Ca. However, other micronutrients that could not be met in terms of requirements can be added through commercial fortification and supplementation to meet the required levels. The research concluded that sesame inclusion in formulation of complementary porridge blends does not have significant negative effect on the sensory attributes of the formulated porridge blends. Sesame therefore can be recommended as a raw material in production of complementary porridge blends. There is potential to yield positive nutrition benefits from the rich nutrient source of sesame while at the same time there is no compromise of sensory attributes to consumers.

6.4.1 Implications to policy

Sesame in Zimbabwe is a new oil seed crop which is mostly grown for commercial purposes in areas like Mt Darwin targeting the Mozambican market while in other areas like Gokwe, few companies are beginning to commercialise the crop. Although traditionally the crop was grown, utilisation of the crop has been low as the farmers grow the crop focusing on selling rather than consumption. The current study concluded that there are a lot of nutritional benefits in using sesame for formulating complementary porridges. Policy that looks at improving agronomic practices of sesame aimed at improving production and household utilisation of the crop at farm gate should therefore be the focus of government policy makers. The government public extension policy should be amended to put more focus on research into sesame in order to develop literature on agronomy as well as the potential nutritional benefits that the crop has in contribution to micro nutrient malnutrition eradication. The current classification of oil seed crops in Zimbabwe considers crops like soybeans, groundnut and cotton. Sesame is not classified under oil seed crops and is a neglected crop yet this study proves that there are a lot of benefits in terms of macro and micro nutrients that are associated with the crop.

The conceptual framework which underpins this study considers household all year round access to health and nutritious food as key in achieving individual nutrition status. Value addition and fortification therefore play a major role in achieving this objective. There is need for government policy to focus on value addition and fortification at household level. The current food fortification strategy is at national level. Little has been done to scale down to household level and yet issues of micronutrient malnutrition are most prevalent at this level. The current study provided evidence that rural marginalised small scale farmers through availability of proper training can produce valuable complementary feeds using their own traditionally grown small grain and legume crops for the benefit of reducing cases of micronutrient malnutrition. There is need for policy makers to tailor make farmer training to move away from traditional agronomic type to value addition and household fortification so that the goals of achieving individual nutrition status are reached.

The food vehicles which are currently being used by the government (cooking oil, sugar and wheat flour) in the National Food fortification program are far from the reach of farmers who currently reside in the smallholder farming set ups. More so knowing that small grains and legume crops are the food security crops for smallholder farmers, policy makers should deliberately turn their focus on crafting policies that promote use of small grain and legume crops in household food fortification as they are cheap sources of both macro and micro nutrients which are critical in reducing prevalence of micro nutrient malnutrition. Cereals and legume crops are cheap sources of nutrients which can be utilised by farmers to reduce cases of micro nutrient malnutrition.

6.5 Areas for further research

The study focused on assessing the contribution of sesame in the formulation of complementary porridges with particular reference to the contribution to both macro and micro nutrients. The study also assessed the sensory attributes of porridge blends formulated using sesame, however, the researcher recommends shelf- life studies on the formulated porridge blends as this could be a guide on the storage ability of the porridge flours looking at the possibility for future use. Farmers in the rural set ups normally have periods of crops availability and times when food gets limited. Shelf life studies would enhance processing and storage of the porridge blends for specific times which would ensure all year availability of nutritious complementary porridges. Further studies on shelf life can also be used to provide guidelines of packaging which could result in availing of the product on the market.

Further studies on the anti-nutritional factors such as phytic acid, tannins, goitrogens, oxalic acid and trypsin inhibitors which are important aspects with regards to bioavailability of nutrients in the porridges are recommended. Due to the high nutritional content of the formulated porridge blends, there is possibility of deterioration and fungal contamination, accompanied by the production of mycotoxins. Although the study used a processing procedure that is known to reduce the amounts of these anti-nutritional factors, the researcher recommends a detailed analysis of the anti-nutritional factors in order to assess bio availability of the required nutrients in the final product.

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6.7 Appendices

APPENDIX I. Questionnaire for sensory evaluation of a sesame fortified porridge

My name is Farai Desire Marongwe and I am currently studying a Master's degree in Food Security and Sustainable Agriculture at Bindura University of Science Education. I am doing a research on the development of a fortified porridge using Sesame and groundnuts as legumes and sorghum and pearl millet as cereals. The questionnaire serves to assess if the porridges made out of the different formulations involving sesame will be acceptable to consumers. Your participation will be greatly appreciated.

Question 1

With reference to the 9 point hedonic scale shown below, please fill in the table below by writing the number that you feel the porridge rates for each category.

Hedonic scale

Dislike extremely	-1	Like slightly	-6
Dislike very much	-2	Like moderately	-7
Dislike moderately	-3	Like very much	-8
Dislike slightly	-4	Like extremely	-9

Neither like nor dislike- 5

		9 point hedonic scale Frequency								
Attribute	**Porridge description**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Appearance	60g Sorghum + 20g Groundnut + 20g Sesame **(B1)**									
	65g Pearl millet + 25g Groundnut + 10g Sesame **(B2)**									
	60g Sorghum + 20g Pearl millet + 15g Groundnut + 5g Sesame **(B3**									
	80g Sorghum + 20g Sesame **(B4)**									
	70g Pearl millet + 30g Sesame **(B5)**									

	75g Pearl millet + 10g Groundnut + 15g Sesame **(B6)**									
	Reference sample (100% sorghum)									
Taste	60g Sorghum + 20g Groundnut + 20g Sesame **(B1)**									
	65g Pearl millet + 25g Groundnut + 10g Sesame **(B2)**									
	60g Sorghum + 20g Pearl millet + 15g Groundnut + 5g Sesame **(B3**									
	80g Sorghum + 20g Sesame **(B4)**									
	70g Pearl millet + 30g Sesame **(B5)**									
	75g Pearl millet + 10g Groundnut + 15g Sesame **(B6)**									
	Reference sample (100% sorghum)									
Flavour	60g Sorghum + 20g Groundnut + 20g Sesame **(B1)**									
	65g Pearl millet + 25g Groundnut + 10g Sesame **(B2)**									
	60g Sorghum + 20g Pearl millet + 15g Groundnut + 5g Sesame **(B3**									
	80g Sorghum + 20g Sesame **(B4)**									
	70g Pearl millet + 30g Sesame **(B5)**									
	75g Pearl millet + 10g Groundnut + 15g Sesame **(B6)**									
	Reference sample (100% sorghum)									
Texture	60g Sorghum + 20g Groundnut + 20g Sesame **(B1)**									
	65g Pearl millet + 25g Groundnut + 10g Sesame **(B2)**									
	60g Sorghum + 20g Pearl millet + 15g Groundnut + 5g Sesame **(B3**									
	80g Sorghum + 20g Sesame **(B4)**									
	70g Pearl millet + 30g Sesame **(B5)**									
	75g Pearl millet + 10g Groundnut + 15g Sesame **(B6)**									
	Reference sample (100% sorghum)									

Question 2

Please rank your samples according to the order of your preference, staring with the highest, i.e. your most preferred sample.

Order(1,2,3,4,5,6)	**Comments**

Sensory evaluation data for the porridge formulations

	Hedonic scale	1	2	3	4	5	6	7	8	9
Appearance	60g Sorghum + 20g Groundnut + 20g Sesame **(B1)**	3	1	3	3	14	23	16	20	17
	65g Pearl millet + 25g Groundnut + 10g Sesame **(B2)**	0	0	3	3	8	24	31	24	7
	60g Sorghum + 20g Pearl millet + 15g Groundnut + 5g Sesame **(B3)**	1	3	4	2	7	3	15	23	42
	80g Sorghum + 20g Sesame **(B4)**	5	9	6	8	15	18	12	26	1
	70g Pearl millet + 30g Sesame **(B5)**	0	1	4	11	10	13	9	23	29
	75g Pearl millet + 10g Groundnut + 15g Sesame **(B6)**	4	6	3	3	9	2	18	27	28
	Reference sample (100% sorghum)	6	4	3	7	23	13	35	5	4
Taste	60g Sorghum + 20g Groundnut + 20g Sesame **(B1)**	3	3	8	3	16	16	23	19	9
	65g Pearl millet + 25g Groundnut + 10g Sesame **(B2)**	0	2	2	5	7	20	30	31	3
	60g Sorghum + 20g Pearl millet + 15g Groundnut + 5g Sesame **(B3)**	0	1	4	11	10	13	9	23	29
	80g Sorghum + 20g Sesame **(B4)**	0	0	2	3	4	11	8	42	30
	70g Pearl millet + 30g Sesame **(B5)**	1	0	4	7	6	16	23	36	7
	75g Pearl millet + 10g Groundnut + 15g Sesame **(B6)**	1	1	3	6	9	22	19	12	27
	Reference sample (100% sorghum)	22	12	18	15	9	9	3	7	5
Flavour	60g Sorghum + 20g Groundnut + 20g Sesame **(B1)**	2	5	3	10	8	20	30	14	8
	65g Pearl millet + 25g Groundnut + 10g Sesame **(B2)**	2	4	4	3	10	21	24	23	9
	60g Sorghum + 20g Pearl millet + 15g Groundnut + 5g Sesame **(B3)**	1	0	1	2	3	8	9	33	43
	80g Sorghum + 20g Sesame **(B4)**	3	2	0	1	5	30	25	21	13
	70g Pearl millet + 30g Sesame **(B5)**	1	0	1	3	2	28	41	15	9
	75g Pearl millet + 10g Groundnut + 15g Sesame **(B6)**	0	1	3	5	16	22	32	17	4
	Reference sample (100% sorghum)	25	21	6	15	16	8	6	2	1
Texture	60g Sorghum + 20g Groundnut + 20g Sesame **(B1)**	0	2	7	3	13	25	30	16	4
	65g Pearl millet + 25g Groundnut + 10g Sesame **(B2)**	0	1	3	16	5	22	32	17	4
	60g Sorghum + 20g Pearl millet + 15g Groundnut + 5g Sesame **(B3)**	0	2	2	2	15	25	31	18	5
	80g Sorghum + 20g Sesame **(B4)**	4	6	1	13	12	25	16	10	13
	70g Pearl millet + 30g Sesame **(B5)**	2	0	4	3	3	15	14	24	35
	75g Pearl millet + 10g Groundnut + 15g Sesame **(B6)**	1	1	3	6	9	22	19	12	27
	Reference sample (100% sorghum)	1	1	3	2	1	6	16	29	41