PROCESS ANALYSIS AND NUTRITIONAL QUALITY OF PORRIDGE COMPOSITE FLOURS DEVELOPED FROM LEGUME-BASED INGREDIENTS GROWN IN NANDI COUNTY

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DECLARATION

This is my original work and has not been presented for a degree in any other university.

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I dedicate this work to God Almighty Who made everything beautiful in His time

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GENERAL ABSTRACT

High malnutrition in Nandi County has created the need for utilization of "nutrient strength" of locally available ingredients in development of a number of multi cereal-legume based composite flour by farmers groups. However, process optimization, consumer preference and acceptability, product safety and nutritional quality of these flours has not been done. This has created the gap in knowledge on the best processing technology and ratio combination of ingredients to ensure nutrients optimization targeting specific demographics. Hence the current study aimed at process optimization, safety and quality analysis and development of most acceptable composite porridge flours using locally available ingredients at Nandi County.

Structured interviews and intervention was done with two farmers groups (Kapkerer and Kiptaruswo) currently involved in composite porridge flour development. A cross-sectional study was done to determine farmers' and consumers' inclination to ingredients used in porridge flour development and to evaluate the processing protocol followed in porridge flour development. Data was collected through focused group discussion, observation and individual interview. Samples obtained from respective farmers groups were used for the study and included; legumes (soybean, groundnut and lablab), cereals (wheat, sorghum, finger millet and maize), pseudo-cereals (buckwheat, amaranth seed and pumpkin seed) and roots (cassava and arrowroot). Nutritional profiling of each ingredient was done as per standard methods. Tannins and phytate reduction in selected grains was achieved by processing technologies like soaking, roasting and boiling. Nutrisurvey linear programming software was used in composite flour formulations and nutrient optimization. The formulated flours were subjected to sensory analysis and acceptability studies. Further, nutritional and anti-nutritional profiling was done for the most accepted composite flour and their control. The most accepted porridge flours and their controls were packaged in kraft paper, gunny bag and plastic container and subjected to Accelerated Shelf Life study (ASLT).

Findings from consumers and farmers inclination to ingredients used in composite flour indicated higher preference of soybean, groundnut, sorghum, finger millet and cassava. This was influenced by the cultural importance attached to specific ingredients, cost, availability and their impact on the sensory attributes of porridge. The processing protocol followed by farmers' groups was inadequate in meeting safe and nutritious products. Legumes and pseudo-cereals were found to be the most nutritious in protein (9.78-41.14%), fibre (7.54-13.70%) and fat (5.70-38.14%). Observed optimal processing treatment included; soaking groundnut, finger millet and soybean for 6 hrs at 1:2 soaking ratio and soaking lablab for 24 hrs at 1:3 soaking ratio and boiling for 60 mins. Consumer acceptability and preference studies showed that the new formulations were the most preferred on color (20-54.2%), smell (40-52.4%), taste (45-47.5%), texture (30-58.3%), viscosity (35.4-45.8%) and overall acceptability (35-54.2%). Reduction of fat content in new formulation while optimizing on nutrient density was achieved. The new formulations were found to degrade slower on safety and quality attributes more so in plastic jars. All the formulations would therefore be kept for more than five months with plastic jars being the best packaging material. Therefore, locally available ingredients are thus nutritious enough to meet with nutritional requirement of vulnerable target groups more so, if properly processed and packaged. Thus if the farmers' group would adopt the observed processing protocols in developing the most acceptable composite flour, there would be customer satisfaction which would create more demand for their product thus reducing malnutrition among children while economically empowering the farmers.

CHAPTER ONE: INTRODUCTION

1.1 BACKGROUND INFORMATION

Protein energy malnutrition is still prevalent in Kenya more so, in Nandi County. In 2007, approximately 51% Kenyans were estimated to be food insecure linked to poverty at 46% (Government of Kenya, 2008) with approximately 1.3 and 3.5-4 million Kenyans in rural areas and urban areas respectively being food insecure (FEWS, 2009). In an effort to solve food insecurity among the many efforts done, plant gene resource (PGR) is greatly being exploited (Wambugu and Muthamia, 2009). Diet is a major factor in the increase of diabetes, hypertension, obesity and other cardiovascular diseases (CVD) components affecting close to 2 billion people world-wide *(Anand et al.*, 2015). Fortunately, increasing legumes in the diet have been shown to combat this metabolic syndrome (Rizkalla *et al*., 2002; Settaluri *et al*., 2012; Bouchenak and Senhadji, 2013; Nielen *et al*, 2014; Marventano,2016).

High economic cost, continuous cropping and climatic changes has resulted to poor land productivity threatening food security, poverty and malnutrition among Nandi farmers who depends on maize and bean for their food and income. Kenya Agricultural and Livestock Research Organization (KALRO) in conjunction with other collaborators who include University of Nairobi, Cornell University, Egerton University, Appropriate Rural Development Agricultural Programme (ARDAP), Rural Energy and Food Security Organization (REFSO) and AVENE Community Organization (ACDO) have conducted studies to help solve the problem. This involved; evaluating bean varieties for resistance to pest and diseases, facilitating farmer verification and adaptive trials to integrate a range of grain legumes into cereal based systems, building capacity of researchers and farmers for systems oriented on farm research through both formal and informal training and engaging stakeholders in legume product development, testing, marketing and scaling successful legume technologies. Achievement have been through working with farmers in groups at Kapkerer, Kiptaruswo and Koibem sites in Nandi County, leading to adoption of Lablab *(Dolichos lablab*), soybean (*Glycine max*) and groundnut (*Arachis hypogaea*) besides common bean (*Phaseolus vulgaris* L) which was already in the system.

Adoption of grain legumes and better farming practices has led to increased output of legumes and cereals necessitating value addition to boost farmers' income and nutritional status of households. To achieve this, farmer groups have developed multi-legume porridge flour which is locally mixed and sold to communities in Nandi County and beyond. This value-added product will consequently result in dietary diversification, health and nutritional benefits, increased household income from both rural farmers and urban based traders.

Despite legumes being highly nutritious, their anti-nutritional composition limits their nutritional quality (Sandberg, 2002; Bouchenak and Senhadji, 2013). Soaking, malting, steaming, germination, roasting and de-hulling are some of the globally adopted process optimization methods used (Waithaka, *et al*., 2013; Ndagire, *et al*., 2015). However, this has not been adopted by the Nandi farmers groups hence their product safety and hygiene is wanting. This can be blamed on their educational background and exposure. Consumer preference and acceptability which has to be experimentally determined is a key parameter in determining composite flour formulation (Hefnawy *et al*., 2012; Tortoe *et al*., 2014; Ndagire *et al*., 2015).

Binary or more mixtures of flours have been globally adopted in processing of different food products especially pastries and bakery products. Wheat flour have been replaced at different proportion with cereals, legumes, tubers and fruit flour while maintaining similar characteristics as products made from full wheat flour (Noorfarahzilah *et al*., 2014). Food deficits and low dietary diversity of both plant and animal food has resulted to nutritional deficiencies causing chronic diseases and death. This has created the need for utilization of local food processing method that maximizes on "nutrient strength" of locally available ingredients in composite flour development resulting in optimization of nutrients in formulation of supplementary foods, reduction of food insecurity, malnutrition and diseases (Kunyanga *et al.*, 2012). This concept have been adopted in Nandi County in development of porridge composite flour targeting different demographics. Although it is a new concept in the area, it has promoted reintroduction of neglected indigenous foods and positive economic impact.

1.2 PROBLEM STATEMENT

High population pressure in Nandi County has resulted to high land fragmentation and continuous cropping. This has depleted the fertility of the soil increasing the vulnerability of plants to pest and diseases resulting to food insecurity, human malnutrition and reduced household income. In an attempt to address this situation, wide range of multipurpose legumes have been introduced in the area to diversify diets, improve nutrition among other benefits. The introduced legumes include; soybean, groundnut and lablab.

High production of legumes crops, has resulted to farmer groups processing them into flour coming up with different mixes to diversify their use and derive maximum nutritional value. However, this form of value addition of multipurpose legume targeting different demographics in the society are yet to be optimized based on nutritional values, safety and consumer acceptability.

Unfortunately, legumes have varying components of anti-nutritional compounds which includes; phytate, haemaglutinins, tannings, trypsin inhibitor, cyanogenic glycosides and oligosaccharides. These anti-nutrients are responsible in reducing the nutritional value of food products by chelating minerals, indigestibility of proteins and flatulence. This has raised concern on the actual nutritional value, quality and safety of developed composite flour. There is needing therefore, to identify the most optimizing processing protocol.

Despite legumes being highly nutritious, their anti-nutrients contents and longer cooking time has resulted to their low acceptance. Food acceptance is also largely determined aesthetically rather than by their nutritional content, legumes not being an exceptional. Hence the current challenge is how to accommodate both the nutritional value of legumes and the aesthetic properties expected by consumers. There is need therefore, to prove consumer acceptability and nutritional composition of the new developed composite flour.

1.3 JUSTIFICATION

The recommended dietary allowance (RDA) of both micro and macro nutrients for different demographics vary (Aggett, et *al.,* 1997). Grains are good sources of fiber, minerals, starch and proteins (Liu *et al*., 2000; Pereira *et al.,* 2002). However, the bioavailability of minerals like iron, magnesium and zinc which are important for growth and development, neurological development, wound healing and immune-competence is lowered by the anti-nutrients present in legumes (Siddhuraju and Becker, 2001; Bouchenak and Senhadji, 2013). There is needing therefore, to subject the newly developed legume-based flour products to safety and quality assessment to ensure optimal availability of key nutrients to the infants, the sick and the grownups in the society.

Adding value to the leguminous grains produced by small holders in Nandi County will not only facilitate diversification of diets but also provide health and nutritional benefits. Taste and consumer preference considerations will be key to ensuring creation of demand for the new product. High product acceptability and adoption by consumers will promote reintroduction of neglected indigenous foods, more dedication of farming land hence higher productivity. This will therefore promote value addition of the surplus, enhanced trading in the new product creating opportunities for both farmers and urban traders to increase on their household income. There is need therefore to ensure consumer acceptability of the developed product.

1.4 MAIN OBJECTIVE

The main objective of this study was to analyze and optimize the process technology and nutritional quality of legume-based composite flour using locally available ingredients in Nandi County, Kenya.

1.5 SPECIFIC OBJECTIVES

1) To determine consumer and farmers' inclination to ingredients used to guide on the development of acceptable legume based composite flour.

2) To formulate and optimize the processing of legume-based composite flour products and process optimization.

3) To determine the acceptability, nutritional quality and anti-nutrient composition of the most accepted developed legume-based flours

4) To determine the shelf life of the most accepted composite flour.

1.6 RESEARCH QUESTIONS

1) Which are the most preferred ingredients among the twelve and what are most common illness that can be addressed nutritionally?

2) What are the best ratios of combining the ingredients to optimize nutrients availability in the legume-based flours for the nutritional target groups?

3) Which is the most acceptable porridge flour and their nutritional quality and anti-nutritional composition?

4) What is the shelf life of the legume-based flour and how can this be extended?

CHAPTER TWO: LITERATURE REVIEW

2.1 OVERVIEW OF FOOD SECURITY IN KENYA

Agriculture is the main economic activity in Kenya having employed over 70% Kenyans directly or indirectly (Glopolis, 2013; Waithaka, *et al*., 2013). Approximately, only 88% of Kenyans households take acceptable meals (WFP, 2016). Justless than one half of the Kenyans live below the poverty line. This limits them from loans, modern technology access, healthcare, information and education. The most threatened groups are the pastoralists in the north, northeast and southwest part of Kenya (Glopolis, 2013).

Over the years, environmental degradation as a result of urbanization, deforestation and development have resulted to climate change (Patel *et al*, 2012). High dependency on unpredictable rainfall patterns due to climate change has compounded food insecurity status in Kenya. This is forcing the poor to reduce their food intake, compromise on quality thus negatively affecting their health (Patel *et al*, 2012).

2.2 MALNUTRITION IN KENYA

Despite the continued effort to fight hunger, a large number of people still lack enough food for an active healthy life. Globally, the prevalence of undernourishment has declined from 18.6 % (1990) to 10.9% (2014-16) and in Eastern Africa it has reduced to 31.5%.This an indication that Kenya has achieved its World Food Summit (WFS) goal of halving the number of undernourished by 2015 (FAO, 2015). According to International Food Policy research Institute, Kenya was ranked fiftieth out of eighty-one countries in 2011 and fifty fourth in 2012 on the index of undernourished population, underweight children under the age of five and child mortality (Glopolis, 2013).

Currently, more than ten millions Kenyans suffer from chronic food insecurity and poor nutrition with between two to four million people requiring emergency food assistance at any given time (Patel *et al*., 2012). However, there has been noticeable decline in malnutrition status of under-fives from 2003-2014 (WFP, 2016).

2.3 INTERVENTIONS TO ADDRESS FOOD SECURITY AND MALNUTRITION

The government has since independence been advocating for conservation, food and nutrition security and proper environmental management (Patel *et al*., 2012). The government has also established national food and nutrition security policy (FNSP) which stipulates the roles the government intends to play specifying the responsible agency (GOK, 2011). A lot of research also being done by both governmental and non-governmental institution with an aim of curbing food insecurity status (Feed the future, 2015). This is in the guideline of the government vision 2030 of not only economically empowering its people but also ensuring food security (GOK, 2011).

2.3.1 Food-Based Interventions

Tropical grain legumes are important in sub-Saharan Africa and South Asia but their productivity is low due to little adoption of technology. However, a successful strategy to raise productivity and revenue from grains are being done by different institutions (Abate and Orr, 2012). More so, both governmental and non-governmental institutions are undertaking school meals programs, Nairobi slums and refugee camp feeding and fortified food supplements to nursing mothers and children (WFP, 2016). Anti-nutritional components of legumes have necessitated advancement in their preparation technology to reduce their content, diversify their utilization hence curb malnutrition. Soaking, germination, fermentation, roasting are some of the optimized technology options (Sandberg, 2002; Megat Rusydi & Azrina, 2012).

2.4 COMMON FOOD INGREDIENTS IN COMPOSITE FLOUR

2.4.1 Cereals

Cereals utilized in the composite flour formulation include; Buckwheat (*Fagopyrum esculemtum*), Amaranth seed *(Amaranthus)*, Wheat (*Triticum aestivum*), Maize (*Zea mays*), Sorghum (*Sorghum bicolor*), Finger Millet (*Eleusine coracana*) and Pumpkin seed (*Cucurbita spp*). Buckwheat is largely grown in China, Ukraine and Russian federation (Christa and Soral-śmietana, 2003). It has health promoting value in alleviating diabetes, obesity, hypertension and hypercholesterolem and it's also a good source minerals (Christa & Soral-śmietana, 2003; Giménez-bastida *et al*., 2015).

Amaranth utilization in the diets have greatly increased especially in people with celiac disease or allergic to typical cereals (Pasko *et al.*, 2009) since it is gluten free (Mlakar *et al.*, 2009)**.** It has the highest lipid content in comparison to other cereals with 75% unsaturated fatty acids. It is also good source of minerals (Mlaka *et al*., 2009)**.** Whole wheat flour is rich in fiber, minerals, phytochemicals, amino acids and fat soluble vitamins (Begum *et al*., 2013). Its scarcity and high demand has necessitated it supplementation. More so, presence of albumin and globulins limits its utilization with coeliac diseased individuals (Šramková *et al.*, 2009).

Maize is a major contributor of starch (72-73%) both for industrial and domestic use, oil and gluten (Adeyeye *et al*., 2017). It is also a staple food to most people world-wide (Bibiana *et al*., 2014). Sorghum is a staple grain in Latin America, Asia and Africa and the 5th most cultivated grain worldwide. It is drought resistant thus very important to millions of people living in semi-arid environments (Adebiyi, 2005). In many parts of the world, it is used in porridge, cookies, unleavened bread, cakes, soft drinks and malted bear (Ediage, 2015). However, its nutritional value is reduced by anti-nutritional composition (WHO, 2012)

Finger millet is very important in the semi-arid regions of Africa and India. It is consumed as bread, soup, cake, porridge or used in beer making (Abubakar *et al.*, 2015). Its protein is of higher quality having 44.75% of the essential amino. Bioavailability of nutritional composition of the nutrients are limited by presence of anti-nutritional composition (Pragya *et al.*, 2015)**.** Pumpkin is a vine crop that is underutilized which plays the role of weed control agent and as cover crop. The leaves are analgesic and hematinic and used in treating burns while the pulp is used in treating enteritis and stomach disorders (Blessing *et al*., 2011). Pumpkin seed are important source of lipids, proteins, minerals and carbohydrates. Thus making it high potential for use in food fortification (Karaye *et al.*,2013).

2.4.2 Root and Tuber Crops

Arrowroot *(Marantha arundinaceae*) and Cassava *(Manihot esculenta)* are the most common roots used. Cassava is drought resistant crop mainly grown in tropical and sub-tropical areas where malnutrition is high making it a great source of nutrition (Montagnac *et al*., 2009a). Cassava contains cyanogenic glucosides made up of Linamarin (Montagnac *et al*., 2009b). Fermentation, drying, grating, crushing, boiling or steaming are some of the methods used to reduce linamarin (Oyetayo, 2006: *Montagnac et al*., 2009b). Grating and crushing have been identified as the most efficient while fermentation has been known to reduce it to 85.6% within 72h (Montagnac *et al.*, 2009b). Besides being utilized as flour, it is also used as a biofuel (Lin *et al*., 2011; Zvinavashe *et al*., 2012) and also in the feed and starch industry (Lin *et al*., 2011). Besides cassava root, its leaves are also being utilized in protein fortification of cassava flour (C de Souza Lima *et al.*,2012).

Unlike cassava and yams which have been largely incorporated in bread making, arrowroot has not received much attention (Ciacco and D'Appolonia, 1977). Nutritional composition of arrowroot was reported to contain approximately 7.72% protein, 62.3% total starch, 29.4%

amylose, 32.8 amylopectin, and 9.4% moisture content (Aprianita *et al*., 2014). Arrowroot was also found to have comparable viscosity peak values to those of yam and taro (Aprianita *et al*., 2014) but lower than reported values in wheat (Mbofung *et al*. 2006). This is very useful in confectionary and weaning foods preparation (Snow and O'Dea 1981; Hoover, 2001).

2.4.3 Legumes

Legumes utilized include; Peanuts /Groundnut (*Arachis hypogaea*), *Soybean* (*Glycine max*) and *Dolichos LabLab* (*Lablab purpureus*). Mostly peanut is pressed for peanut oil, eaten as whole or sprinkled onto food or included in other dishes (Ros, 2010). The roasted edible portion of the peanut has saturated fats, mono unsaturated fats (oleic acids) and poly unsaturated fatty acids (Settaluri *et al.,* 2012). They also contain minerals and vitamins (Blomhoff *et al*., 2006). Unfortunately, they have allergic reaction especially to children (Lack *et al*., 2003). However, they have been used in composite porridge flour (7.8%) formulations targeting children in an effort to meet their nutritional requirements (Ouédraogo et al., 2009) Besides being utilized as food, it is also used as animal feed and its by-products utilized in production of non- food products (Kain & Chen, 2010). Soybean belongs to the pea family growing in tropical, subtropical and temperate climatic zones. (Dugje *et al.*, 2009). Its high nutritional and sensory attributes (Dugje *et al*., 2009; Noorfarah *et al*., 2014) have encouraged its utilization in confectionery (5%) (Aluge, *et al*.,2016), bread (5-12%) (Ribotta, *et al.*, 2005 2005), 10-40% (Ndife, *et al*., 2011) and composite flours (Edema,*et al*., 2005) developments. However, it's anti-nutritional composition reduces its nutritional value (Gu *et al*., 2010).

Lablab is both drought and shade resistant thus a potential protein source for human and animals (Shaahu, *et al*.,2015). However, its poor eating quality, longer cooking time and high cynide level which requires pouring out first boiling water has reduced its adoptability (Shivachi *et al*., 2012). More so its anti-nutritional constituents reduces its nutritional quality and digestibility of its proteins (Shaahu *et al*., 2015). However, it has been incorporated in different composite flour at varying ratios 5-20% in bread (Kunyanga and Imungi, 2010) after treatments to reduce its anti-nutritional constituents and beany flavor (Kunyanga and Imungi, 2010, Shaahu *et al*., 2015).

2.5 LEGUME PROCESSING PROTOCOLS AND NUTRITIONAL QUALITY

Anti-nutritional composition of legumes reduces their nutritional bioavailability (Bouchenak and Senhadji, 2013). Soaking, germination, fermentation and hydrothermal treatment are some of the adopted optimization solutions (Sandberg, 2002). Phytate can be reduced by 90%, 50-64% and 47-98% by fermentation, germination and soaking respectively. Sprouting and roasting are undesirable due to increasing fibre content (Hotz and Gibson, 2007) and reduction of starch (Nithya *et al*., 2007) respectively. Nutritional optimization by using more than two ingredients complicates the rationing (Ndagire *et al*., 2015) necessitating the use of optimization software (Ouédraogo *et al*., 2009; Tortoe *et al*., 2014).

In Uganda, bean flour was initially processed by soaking (12 hours) →Malting (48 hours) → de-hulling → steaming (15 minutes) → roasting (15 minutes) but later optimized by halving the malting time, increasing the steaming time by five minutes and replacing roasting with oven drying to prevent the roasted flavor (Waithaka *et al*., 2013). Mazur *et al*., (2012) optimized similar process and arrived at starch and protein digestibility of 91.16 and 87.73% respectively while phytate and polyphenols levels were 0.22% and 0.58 % respectively. Ndagire *et al*., (2015) optimized bean flour processing resulting to phytate and polyphenol content of 0.22 and 0.57% respectively with high protein and starch digestibility of 91.6% and 87.73% respectively. Soybean and peanuts being fatty legumes, de-fattening (roasting) maybe a necessary step to reduce on shelf life compromise of the flour (Ouédraogo *et al.*, 2009: Tortoe *et al.*, 2014: Bolarinwa *et al.*, 2015).

2.6 CEREAL AND ROOTS PROCESSING PROTOCOLS AND NUTRITIONAL QUALITY

Cereals are good sources for dietary fibre and many bioactive compounds eg minerals, tocopherols, phytosterols, lignans and phenolic acids. Their whole grain consumption have been associated with reduced diabetes mellitus (Liu *et al.*, 2000; Pereira *et al.,* 2002), cardiovascular diseases (Jacobs *et al.*, 1998) and colon cancer (cCullough *et al.,* 2003). However, cereals are limited to their nutritional composition in comparisons to legumes (Tharanathan and Mahadevamma, 2003; Embaby, 2010). This has encouraged food to food fortification of cereal based products with legumes or roots (*Pelembe et al.*, 2002; Bojnanská *et al*., 2012; Hefnawy *et al*., 2012; Kohajdová *et al*., 2013). More so, cereals have got anti-nutritional compounds which further lowers their nutritional status (Makokha *et al.*, 2002; Osman, 2011; Abubakar *et al*., 2015) . Thus soaking (Egli *et al.*, 2002), fermentation (El Hag, *et al*., 2002; Osman, 2004), decortication (Chiremba *et al*., 2009; Viswanath, *et al*., 2009), germination (Subba and Muralikrishna, 2002; Bvochora *et al.,* 2005) and thermal processing (Towo *et al.,* 2003; Chandrasekara *et al*., 2012) have been adopted in an effort improve on their nutritional levels.

Linamarin poisonous to human consumption is found in cassava (C de Souza Lima *et al.,* 2012). Based on cynide content, cassava has been classified as sweet or bitter cassava (Aloys and Zhou, 2006). Fortunately, there have been adopted measures for its reduction; soaking, fermentation, chopping and drying in an effort to reduce it (Aloys and Zhou, 2006; Bradbury *et al*., 2011)

2.7 CONSUMER PREFERENCE AND ACCEPTABILITY OF NEW PRODUCT

Consumer acceptability is directly proportional to consumer preference of product quality; color, flavor, thickness, appearance, smell, taste and texture. Different processing protocol and combination ratios are a factor. Past panelist knowledge on similar product or training is vital in getting accurate information (Tortoe *et al*., 2014; Ndagire *et al*., 2015). Tortoe *et al*., (2014) found porridge flour with the highest legume proportion(30-40%) to be the least preferred unlike legume flour of (10-29%) being most preferred. Apart from anti-nutrients which limit nutritional level of new products, processing methods used should remove the beany flavor (Kunyanga and Imungi, 2010, Shaahu *et al.*, 2015) undesirable in legume containing products. Therefore, substitution percentages and types of legumes used should be experimentally determined depending on type of product and purposed objectives (Hefnawy *et al*., 2012).

2.8 KNOWLEDGE GAP

Multi-legume based flour has been in production locally by the farmer groups for a while in Nandi County. However, optimum process, consumer preference and acceptability, product safety and nutritional quality has not been done creating a gap in knowledge on the best technology and ratio combination of ingredients to ensure nutrients optimization targeting specific demographics. The actual shelf life of the legume-based products has not been systematically evaluated in Nandi County. This has hence created the need for the current study.

CHAPTER THREE: STATUS OF UTILIZATION AND CONSUMPTION OF LEGUME BASED COMPOSITE PRODUCTS IN KENYA: A CASE OF NANDI COUNTY

ABSTRACT

Protein energy malnutrition is highly prevalent among low income earners in rural communities in Kenya. This has necessitated the need to diversify the local diet. Fortunately, legumes such as soybean, groundnut and lablab bean are nutritious and affordable sources of protein compared to animal sources and also bring about spectra of taste and texture in the diet. Legumes have been largely used in making of bread and pastries. However, their use in development of composite flour for porridge making has been limited especially in Kenya. A cross-sectional study involving two farmer groups (Kapkerer and Kiptaruswo) and medical officers in their neighborhood was conducted in the current study. Data were collected through focus group discussion observations and structured interviews. The study was aimed at assessing the status and utilization of different local food ingredients; farmers' understanding of the nutritional richness of each ingredient, other uses of the flour, the preparation protocols, nutrition related illness common in the area, their preferred ingredient in relation to: cost, taste, color, smell, flavor, cultural values and texture. Results indicated that twelve ingredients were being used; lablab (*Lablab purpureus*), soybean (*Glycine max)*, groundnut (*Arachis hypogaea)*, finger millet (*Eleusine coracana)*, sorghum (*Sorghum bicolor*), maize (Zea mays), wheat (*Triticum aestivum)*, buckwheat (*Fagopyrum esculemtum)*, amaranth seed (*Amaranthus*), pumpkin seed (*Cucurbita spp)*, arrowroot (*Marantha arundinaceae*) and cassava (*Manihot esculenta*). Soybean was the most preferred legume due to its nutritional richness, taste and flavor while millet was the most preferred cereal due to its good taste and color. Wheat was the least preferred cereal since it is costly and of low nutritional value in comparison to other ingredients. Sorghum, millet and

pumpkin seed were culturally valued for reducing prevalence (%) of diarrhea, measles and worms in children respectively. Poor hygiene was observed during processing. Malnutrition and diabetes mellitus were found to be common among children and adults, respectively. There was need therefore to train farmers on better handling of ingredients and products as they are guided on nutrient optimization of their ingredient targeting the current needs of their immediate society.

3.1 INTRODUCTION

Legumes, cereals and roots have intensively been utilized in local diets for diversification in an effort to fight malnutrition (Siddiq *et al*., 2010; Bojnanská *et al*., 2012; Hefnawy *et al*., 2012; Ndagire *et al*., 2015). Legumes have high nutritional value in terms of protein (20-40%), fat (2-3%), carbohydrates (50-60%), minerals (2-4%) and B-complex vitamins (Garg and Dahiya, 2003; Kohajdo *et al*., 2013) and bring about spectre of taste and texture in a dish (Garg and Dahiya, 2003). Their high nutritional value have been utilized in supplementing cereal based diets (Garg and Dahiya, 2003) hence increasing legumes utilization (Kohajdová *et al*., 2013). Legumes are high in lysine but deficient in sulphur containing amino acids which are present in cereals thus their combinations bring about balance of essential amino acids which are very important in the diet (Kohajdová *et al*., 2013). Legumes have been known to control metabolic disease (Rizkalla *et al*., 2002; Settaluri *et al*., 2012; Bouchenak and Senhadji, 2013; Marventano, 2016) such as cardiovascular disease, diabetes mellitus and some form of cancer (Siddiq *et al*., 2010). For instance, decrease in cancer have been associated with presence of fiber, phenolic compounds and other non-nutritive compounds (Oomah *et al*., 2006).

Despite legumes being highly nutritious, their anti- nutritional composition limit their maximum nutritional utilization (Bouchenak and Senhadji, 2013) and hence methods on their reduction such as soaking, boiling, fermentation and sprouting have been adopted (Sandberg, 2002).

Depending on the methodology and legumes type, phytate can be reduced by 90%, 50-64% and 47-98% by fermentation, germination and soaking, respectively. Germination, is however limited by formation of more fiber and reduction of starch from synthesis of more cells for the new seedling (Hotz and Gibson, 2007).

Legumes have various functional properties such as oil and water absorption, emulsion capacity, emulsion and, foaming capacity and foaming stability which are important in ensuring consumer acceptability of legume products (Kaur *et al*., 2007). Composite flours are important due to their economic and nutritional advantages. Composite flour containing wheat and legumes is highly being utilized in the world with the mixing done to produce high quality product in an economic way (Kadam *et al*., 2012). Composite flour development have been largely utilized by researchers especially in production of pastries and bakery products (Noorfarahzilah *et al*.,2014). However, limited information and data is available on status of actual utilization or incorporation of legumes in composite flours and socio-cultural aspects on their use in Kenya. The aim of the current work was to identify the most preferred ingredients of the porridge composite flour among the cereals, legumes, roots and tubers used in respect to; taste, color, texture, cultural values and ease of availability.

3.2 RESEARCH METHODOLOGY

3.2.1 Study Setting

The study area was in Nandi County in Western Kenya purposively chosen due to presence of two farmer groups at Kapkerer and Kiptaruswo with 9 and 12 members, respectively. These two groups are involved in composite flour processing using legumes, cereals and roots then selling to nearby schools and customers from their respective shops. Nandi County is in the North Rift of Kenya (Western Kenya) occupying 2884.4 sq km bordering Kakamega, Uasin Gishu, Kericho, Kisumu and Vihiga Counties to the West, North East, South East, South and South West respectively. Nandi County receives an average of 1200mm to 2000mm of rainfall per annum with the long rains in March to end of June while the short rains start in mid-September to end of November. The driest season is between December and mid-March. Nandi County is Sub-divide; into five sub Counties; Nandi Central, North, East, West and Tinderet. Nandi South where the study will be based occupies 525.4 sq Km. Figure 3.1 below shows the map of Nandi County.

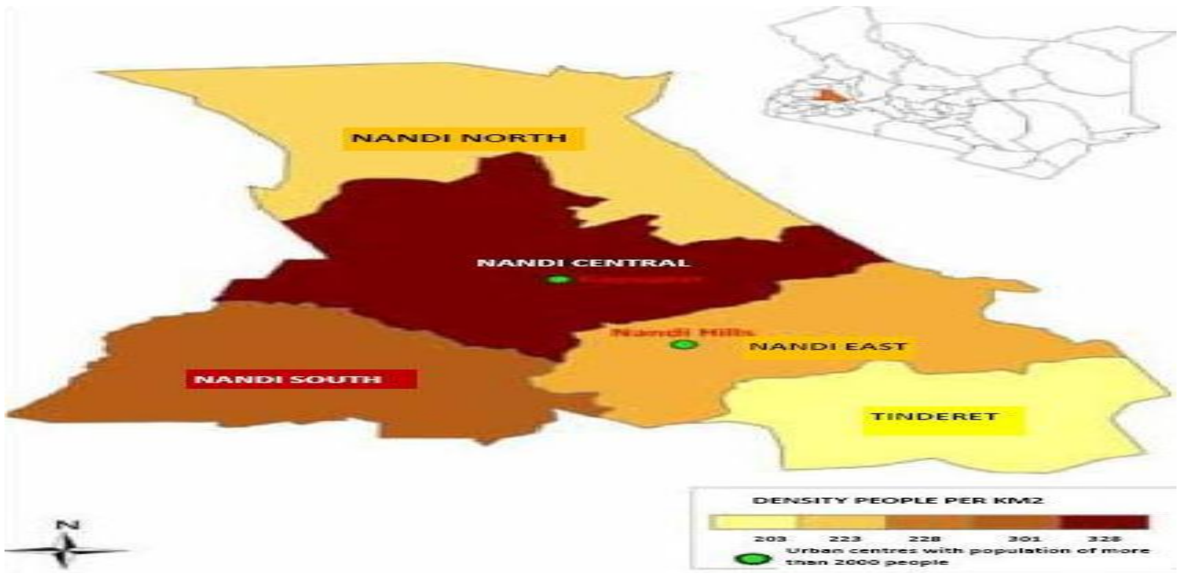

Figure3.1: Map of Nandi County.

3.2.2 Data Collection

Qualitative methodology was used during this cross-sectional study. Data was collected through focus group discussion, observations and individual interviews. A question guide was used during the discussions with the farmers while the medical officer filled in an open ended questionnaire (Appendix 1). The farmer groups involved included: Kapkerer (3 men, 6 women) and Kiptaruswo (5 men, 7 women) self-help groups. The groups were purposively chosen since they were the only groups producing porridge composite flour under Mcknight Multi-Purpose Legume Project. Some of the farmers' feedback and information given by medical officer determined consumers' preference on the porridge flour. Focused group discussion was intended to find out; The type and source of each ingredient used, farmers understanding on nutritional richness of each ingredients, the most preferred ingredient on; taste, color, smell, texture, cultural values and cost, the most key ingredients according to their customers, other uses of the composite flour besides porridge, farmers understanding on the need of each processing step followed and finally other products beside flour they consider producing. The questionnaire filled up by medical practitioners was intended to find out the most common nutrition related illness, its demographic prevalence and the nutritional recommendation given to the affected individuals.

3.2.3 Data Analysis

The qualitative data from focused group discussions and interviews with medical officers was analyzed by Nvivo software to bring out the narratives.

3.3 RESULTS AND DISCUSSION

3.3.1 Type of Ingredients Utilized by the Farmers' Groups and Their Cost

Kiptaruswo and Kapkerer farmers' groups utilized varying number of ingredients costing differently (Table 3.1). Kapkerer group used eight ingredients which included; maize, millet, sorghum, dolichos lablab, groundnut, cassava, soybean and amaranth seed while Kiptaruswo group had an additional of four ingredients; pumpkin seed, arrowroot, buckwheat and wheat. Hence the varying utilization rate (100 or 57 %). Different ingredients had varying prices ranging between Kes 50- 150 per kg. Amaranth seed, groundnut and pumpkin seed were the most expensive (Kes 150) while maize (Kes 50) and cassava (Kes 60) were the cheapest.

Table 3.1: Utilization of ingredients by different farmers' groups and their cost

	Ingredients Used											
	Cassava	Arrowroot	Maize	Buck Wheat	Wheat	Finger millet	Sorghum	Amaranth Seed	Groundnut	Soybean	Lablab bean	Pumpkin seed
Cost (Kes /Kg)	60	75	50	125	80	100	60	150	150	75	100	150
Utilization (%)	100	50	100	50	50	100	100	50	100	100	100	50

3.3.2 Nutritional, Cultural and Organoleptic value of ingredients utilized

Table 3.2 shows nutritional, cultural and organoleptic value attached to identified ingredients utilized. The farmers were informed of nutritional richness of most ingredients. Groundnut, soybean and lablab bean were perceived to be the most nutritious ingredients in protein, fats and minerals. Roots and cereals were perceived to be less nutritious. Previous groups training on the same influenced this. Utilization of higher number of ingredients resulted in their consumers' preference for their products due to their perceived high nutritional level. These findings were consistent with Alamu *et al.* (2016) findings on higher preference for fortified maize flour with sorghum and groundnut due to the perceived increased nutritional status. Groundnut, pumpkin seed and soybean were indicated as major contributors of fats while finger millet and cassava as the best sources of energy. Farmers identified different ingredients that could contain highest mineral content. Iron was identified to be highest in lablab bean and amaranth seed, calcium being highest in finger millet and soybean while zinc was perceived to be highest in lablab bean, soybean and amaranth seed. Thus, farmers showed a higher nutritional preference of legumes to cereals.

Some ingredients were culturally known to treat some diseases. Farmers believe finger millet, sorghum and pumpkin seed treat measles, diarrhea and deworms children respectively. However, this contradicts with Saleh *et al*., (2013) on millet which due to its probiotic factors (Soumya *et al*., 2016) was indicated to reduce diarrhea. Pumpkin seed have largely been adopted in development of traditional herbal medicine for deworming (Caili *et al*., 2006) . This is in consistent with Kiptaruswo farmer's reason for adding pumpkin seed in their flour.

On organoleptic characteristic of the flour; Finger millet and sorghum were preferred for their taste and color This was consistent with Saleh *et al*., (2013) findings. Groundnut and soybean were preferred for their smell while cassava was preferred for its smooth texture and satisfying effect. Thus, their proportion in the composite flour would influence organoleptic preference of the composite porridge flour as evidenced by Pelembe, *et al*., 2002; Patel and Seetharaman, (2010); Tortoe *et al*. (2014) and Ndagire *et al.* (2015) findings.

Table 3.2: Nutritional, cultural and organoleptic importance of ingredients utilized

	Ingredients							
	Cassava	Finger millet	Sorghum	Amaranth Seed	Ground-nut	Soybean	Lablab bean	Pumpkin seed
Perceived Value								
Nutritional*	Energy	Energy and Ca	N/A	Fe and Zn	Protein, Fats and Fe	Protein, Fats, Zn and Ca	Protein and Zn	Fats
Cultural	N/A	Measles	Diarrhea	N/A	N/A	N/A	N/A	Deworming
Organoleptic	Smooth Texture	Taste, Color	Color	N/A	Smell	Smell	N/A	N/A

N/A; Not applicable, *Zn – Zinc, Ca – Calcium, Fe -iron

3.3.3 Occurrence and Prevention of Diet Related Diseases and Other Composite Flour Utilizations

Table 3.3 summarizes other composite flour utilization by consumers besides in porridge making, diet related illness and their control. The medical officers indicated diabetes mellitus was highly prevalent among the adults which conformed with Soriguer *et al*., (2012) findings while malnutrition was prevalent among children below five years old. Poverty or nutritional ignorance has resulted in many parents and their children feeding on starchy food hence the high prevalence of malnutrition and diabetes mellitus. Food to food fortification of starchy foods with legumes and animal based products was recommended by the medical officers for malnourished children while diabetic adults were advised on consuming whole grains based products especially legumes. This was consistent with Siddiq *et al*., (2010) findings. Besides making porridge, some farmers indicated that their consumers used the flour to make some extrusions, substituting wheat in wheat products and cooking stiff porridge (*ugali*). Similar utilization of composite flour besides in porridge have been studied (Alonso *et al*., 2000; Adebowale *et al.*, 2017).

Table 3.3 Diet related illnesses, their control and other flour utilizations

Diet related diseases	Recommended diets	Other flour utilization
Diabetes Mellitus	Whole grain products	Extrusions Stiff porridge Wheat products substitution
Malnutrition	Protein rich products Legume based porridge flour	

3.3.4 Processing Protocol of Ingredients

Figure 3.2 shows the processing protocol followed by the farmers' groups. Farmers' processing steps was wanting since their hygiene level was poor. Cleaning of cereals and legumes was selectively done depending on visibility of dirt or pesticides. Cassava and arrowroot were the only consistently cleaned ingredients due to soil after harvesting. Drying of ingredients was not effectively done especially in wet season more so, it was difficult to confirm their complete dryness without a moisture meter. Cleaned and dried ingredients were stored in gunny bags which attracted dust and were permissive to pest. Personnel hygiene through cleaning hands or wearing protective clothes was inconsistence.

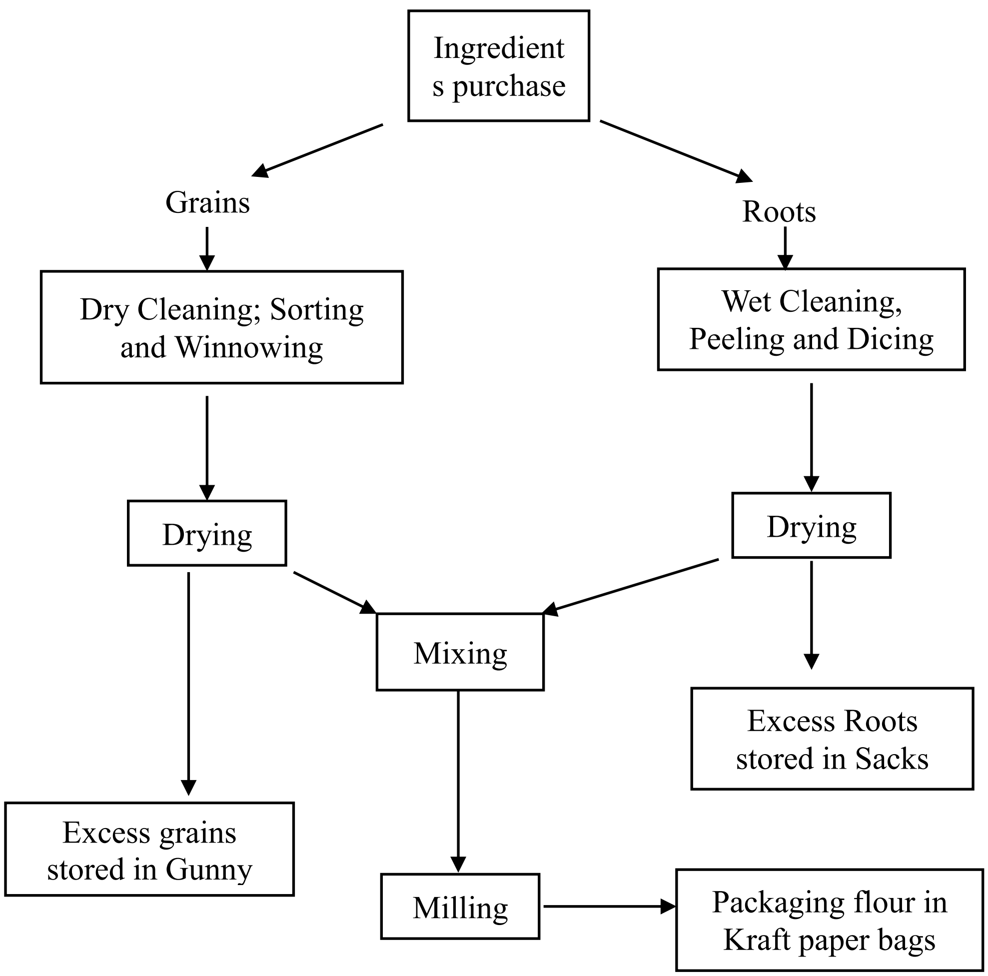

Figure 3.2: Processing protocols Followed by Farmers' Groups

CHAPTER FOUR: PROCESS OPTIMIZATION AND DEVELOPMENT OF A MULTI-MIX COMPOSITE FLOUR

ABSTRACT

Food based interventions using blended composite flours have been shown to reduce malnutrition in Africa. High prevalence of protein energy malnutrition among children has encouraged research on nutrient dense products development from locally available food ingredients. The current study aimed at identifying the most nutritious food ingredients, optimizing processing steps and formulating nutrient dense composite porridge flours. Samples included legumes (soybean, groundnut and lablab), cereals (wheat, sorghum, finger millet and maize), pseudo-cereals (buckwheat, amaranth seed and pumpkin seed) and roots (cassava and arrowroot). Nutritional composition for each ingredient was done according to standard methods. Process optimization enhancing nutrient density and reduction of tannins and phytate in legumes and finger millet was done by soaking, roasting and boiling. Nutrisurvey linear programming software was used in composite flour formulations. The new formulations targeted school going children and a whole family set up aiming to meet optimal levels of protein, energy, calcium, iron, zinc and magnesium.

Optimal treatment observed included; Soaking finger millet, groundnut and soybean for 6 hrs at 1:2 soaking ratio and soaking lablab for 24 hrs at 1:3 soaking ratio and boiling for 60mins. The optimal treatment resulted in phytate reduction of 70% (groundnut), 39% (soybean) but insignificance increase in lablab bean (2%) and finger millet (25%). Tannins reduced in all samples by; 79% (finger millet), 49% (groundnut), 70% (soybean) and 87% (lablab bean).

The new formulations had increased proportions of finger millet and cassava but reduced maize proportions. Arrowroot, buckwheat and wheat were eliminated from the new formulations.

Pumpkin and amaranth seed were limited to children flour while Lablab bean was limited to family flour formulations. There was 100% achievement of the targeted nutrients levels in the new formulations except fats (48-75%) that was purposively kept low. Magnesium and iron were the most concentrated minerals (>200%) while calcium (101-148%) and zinc (100-135%) were achieved at a lower concentration. The highest chemical values found in the ingredients were; 10.51% moisture, 46.29% fats, 41.14% protein, 13.70% fibre, 5.04% ash, 84.71% carbohydrates, 582.69Kcal/100g energy, 3.25mg/100g zinc, 257.50mg/100g calcium, 416.00mg/100g magnesium and 31mg/100g iron. Legumes and pseudocereals were found to be the most nutritious while roots were the poorest. Therefore, locally available ingredients if properly processed and formulated, nutritional requirement of the target groups can be adequately achieved.

4.1 INTRODUCTION

Food insecurity in Kenya has made cereals and roots crops which are drought resistant, highly productive and cheap as staple food (Adebiyi, 2005; Montagnac *et al*., 2009a; Ediage, 2015; Adeyeye *et al*., 2017). However, they are less nutritious than legumes hence the high prevalence for Protein Energy Malnutrition (PEM) (Osman, 2007; Rocha-Guzman *et al.*, 2007).

Fortunately, in addition to legumes being more nutritious than cereals (Adewusi and Falade, 1996; Tharanathan and Mahadevamma, 2003; Embaby, 2010), they have lysine amino acid which is absent in cereals and roots hence their inclusion in the diet promotes a balanced diet (De la Hera, *et al*., 2012). This has encouraged fortification of cereal based products with legumes; porridge *(Pelembe et al.*, 2002), Bread (Bojnanská *et al*., 2012; Hefnawy *et al*., 2012), spaghetti (Arab *et al*., 2010), biscuits (Kohajdová *et al*., 2013) and cake (Abou-Zaid *et al*., 2011; De la Hera *et al.*, 2012) in an effort to curb malnutrition.

However, despite legumes being highly adapted to different climatic conditions, only a few have been extensively promoted and used (Osman, 2007). More so , they have anti-nutritional compounds; tannins and phytate which reduce their nutritional value (Siddhuraju and Becker, 2001; Salariya, 2005; Frontela *et al*., 2008).

phytate (myoinositol hexa-phosporic acid,IP6) and tannins lower nutritional quality of legumes and cereals by chelating tri (iron) and divalent (calcium, zinc and magnesium) minerals (Siddhuraju and Becker, 2001) to form insoluble salts with poor absorption (Adewusi and Falade, 1996; Frontela *et al.*, 2008) and also inhibit protein and starch digestibility (Salariya, 2005).

Tannins are largely concentrated in the seed coat (Elias et al., 1979; Pastuszewska *et al.*, 2004; Rocha-Guzman *et al.*, 2007) with their concentration correlating with the seed coat color intensity (Elias *et al.*, 1979). They form complexes with proteins inhibiting their digestibility *(*Lewu *et al.*, 2009). However, tannins and phytate have been identified to be of benefits to health for instance; high antioxidant activity (Turkmen *et al.*, 2005; Roy *et al*., 2007), anti-carcinogenic activity (Roy *et al.*, 2007), lowering chronic inflammation and chances of diabetes mellitus (Bouchenak, 2013), obesity (Bouchenak, 2013) and cardiovascular disease (Marventano, 2016). Hence, the anti-nutritional effect of phytate and tannins needs to be evaluated against their beneficial properties (Khandelwal *et al*., 2010).

Soaking (Huma *et al*., 2008; Khandelwal, 2010), fermentation (Khattab and Arntfield, 2009), germination (Khandelwal *et al.*, 2010), enzyme inoculation (Matuschek *et al.*, 2001) and heat treatments (Rocha-Guzman *et al.*, 2007; Huma *et al*. 2008; Khandelwal *et al.*, 2010) are some of the methodologies proved to decrease anti-nutritional constituents

Therefore, this study work aimed at process optimization of each ingredient, profiling their nutritional richness thus formulating a nutrient dense composite porridge flour.

4.2 MATERIALS AND METHODS

4.2.1 Sample Collection

Sample ingredients collected for formulation and analysis included; lablab (*Lablab purpureus*), soybean (*Glycine max)*, groundnut (*Arachis hypogaea)*, finger millet (*Eleusine coracana)*, sorghum (*Sorghum bicolor*), maize (Zea mays), wheat (*Triticum aestivum)*, buckwheat (*Fagopyrum esculemtum)*, amaranth seed (*Amaranthus*), pumpkin seed (*Cucurbita spp)*, arrowroot (*Marantha arundinaceae*) and cassava (*Manihot esculenta*). They were obtained from two farmers groups producing legume based porridge flour to economically empower their members and to mitigate malnutrition in children and vulnerable groups in Nandi County, Western Kenya. The farmers' groups obtain the ingredients by purchasing from neighboring Serem market Centre or from their fellow members and store them collectively in sacks. Respective ingredients stored in sacks were mixed before sampling 3Kg of each, packaged separately and transported to food analysis laboratory at University of Nairobi for analysis.

4.2.2 Sample Preparation

All the cereals and legumes were sorted and washed with portable water while the roots were washed, peeled and chopped. Drying of all samples was done in an air oven at 64 ± 2^{0}C (Memmert, Germany) for 24 hrs before grinding using a black & Decker grinder and sieved through 600 μm for uniformity.

4.2.3 Composite Flour Formulations

Figure 4.1 summarizes the processing steps followed in composite flour formulation. Two types of composite flour were developed; for school going children and for a whole family set up.

Farmers groups had varying number of ingredients hence composite fours developed were different. Apportioning of each ingredient was based on findings from focused groups discussion (Unreported results), their nutritional profile found aiming to meet Recommended Dietary Allowance (RDA) of an expectant mother (>4months expectant) by World Health Organization (WHO). Fulfillment of expectant mother nutritional requirement was assumed adequate for every family member. Nutrisurvey Linear programming software embedded with WHO RDA for expectant mothers was used in composite flour formulation. Formulations targeted achievement of 100% of all nutrients except for fats that was thought to cause flour spoilage by oxidation.

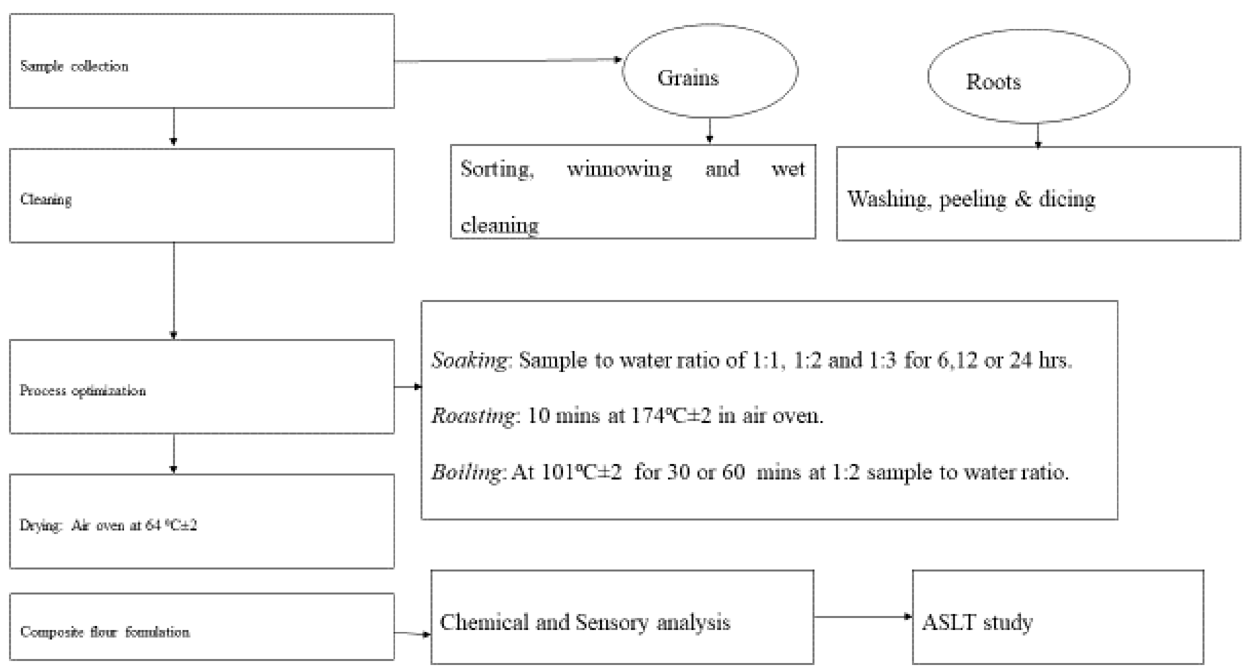

Figure 4.1: Process flow diagram of nutrient dense composite flour development

4.2.4 Process Optimization Study Design

Process optimization study design aimed identifying the optimal treatment for reducing tannins and phytate in lablab, groundnut, soybean and finger millet by soaking, roasting and boiling .

Soaking: whole grain sample of groundnut, soybean and finger millet (100 g each) and lablab

(300g) were soaked separately using different sample to water ratio 1:1, 1:2 and 1:3 at room temperature (22-25^{0}C). Samples were soaked at different hours (6, 12 or 24). Soaking water was changed after 12 hrs for samples soaked for 24 hrs.

Roasting: Dry whole grain samples of groundnut and soybean were roasted for 10 mins at 174±2^{0}C in an air oven (Memmert, Germany). The grains were evenly spread on a tray to ensure uniform heat exposure to all grains.

Boiling: Only lablab was boiled. Each lablab sample (soaked and un-soaked) was sub-divided into three sub-samples of 100g. The first one was boiled for 30 mins the second one for 60 mins while the third one was not boiled. Boiling was done at 101^{0}C in a sample to water ratio of 1:2.

4.2.4.1 Determination of Phytate:

Phytate were analyzed according to the method described by Latta and Eskin, (1980) . A sample of 1g was defatted by adding 10ml of petroleum ether and left to stand for 2 hrs, decanted and let to dry. Hydrochloric acid (10ml at 2.4%) was added to the dried samples and centrifuged (Dr. Ngerber, K.Schneider & co, Zurich, Centrifuge) for 10mins at 482.97g. Centrifuging was repeated four times, each time the supernatant was collected in 100ml volumetric flask. Wade reagent (2ml mixture of 0.03 % Iron chloride and 0.3% sulfosalicyclic acid) was added to 2ml of sample solution and topped up to 10ml. Absorbance was read at 500nm (Single beam spectrophotometer, Milton Roy Company, Spectronic 1001, USA). Phytate content was calculated as g/100g using phytic acid standard curve prepared as described by Latta and Eskin, (1980).

4.2.4.2 Determination of Tannins

Tannins were analyzed as per AOAC (2012) 19th edition, method number 952.0 with modification. Follins denis reagents was prepared as per Ferreira et al., (2004). Approximately

0.5g sample was extracted with 50ml of distilled water, vortexed for 5mins and left to decant. Folins Denis reagent (2ml) was added to 75ml of distilled water followed by 2ml of sample solution and finally 5ml of concentrated sodium carbonate was added. The total mixture was topped up to 100ml, vortexed and left to stand for 40mins before reading absorbance at 725nm (Single beam spectrophotometer, Milton Roy Company, Spectronic 1001, USA).

4.2.5 Chemical Analysis

4.2.5.1 Proximate Analysis

Samples moisture content was determined according to AOAC, (2008 method 967.08).

Kjeldahl method (AOAC, 2008 method 988.05) was used in protein analysis, total nitrogen was multiplied by factor 6.25.

Fat content were analyzed by soxhlet method (AOAC, 2008 method 2003.06).

Dietary fiber was determined by gravimetric method (AOAC, 2008 method 958.06).

Ash content was according to AOAC (2008 method 942.05).

Caloric value was determined by Wilwater conversion factor; Energy= 4 kcal /g (protein) + 9 kcal/g (fat) + 4 kcal/g (carbohydrates) based on Pearson, (1976) formula.

Carbohydrates were determined by the difference: Carbohydrates = [(% 100-(% protein+% fats+% moisture+% ash+% dietary fiber)].

4.2.5.2 Mineral Analysis

Samples were analyzed for iron, zinc, calcium and magnesium according to Puwastien *et al.*, (2011). To 0.5g sample, a mixture of conc. Nitric acid and hydrogen peroxide (5:3) was added and left to stand overnight in a fume chamber before digesting at 110^{o}C for 3 hrs or until a clear or milky digest was found. The digest was topped up to 50ml with deionized water for respective mineral analysis. Atomic Absorption Spectrophotometer (AAS) machine was used in the mineral analysis.

4.2.6 Data Analysis

All the analyses were done in duplicate and results tabulated as means plus or minus standard deviations (SD). The means were subjected to a one way analysis of variance (ANOVA) using Gentstat 15th edition. Fisher's protected LSD multiple range test and difference was considered significance at $p<0.05$

4.3 RESULTS AND DISCUSSION

4.3.1 Composite Flour Formulation

4.3.1.1 Ingredients Proportion in Legume-Cereal-Root Based Flour Formulation

Table 4.1 shows initial and newly formulated composite porridge flours targeting different demographic for each farmers' group. The proportion of each ingredient is shown in % per kg of each composite flour. Initial formulations were A and B for Kiptaruswo and Kapkerer farmers group respectively. School going children and family flour formulations were C, D and G, H for Kiptaruswo and E, F and I and J for Kapkerer farmer' groups, respectively. In all formulations, there was a decrease in maize content but an increase in finger millet.

There was an increase in buying price (kes) for new formulations. Highest price (kes) increase was found in children flour formulations due to replacement of maize with more nutritious but costlier ingredients. Price increase (kes) in family flour formulation was largely contributed by slight replacement of maize with zinc and calcium (mg/100g) richer ingredients (finger millet, soybean, pumpkin and amaranth seed) which were slightly costly. However, caution to prevent very high price (Kes) increase was taken by addition of cassava which also had high zinc levels (1.57mg/100g).

4.3.1.2 Achievement of Each Nutrient Against the Target

Fig 4.2 and 4.3 shows percent achievement of nutrients in composite porridge flour targeting a family set up and school going children respectively against WHO, RDA for a 4mo expectant woman.

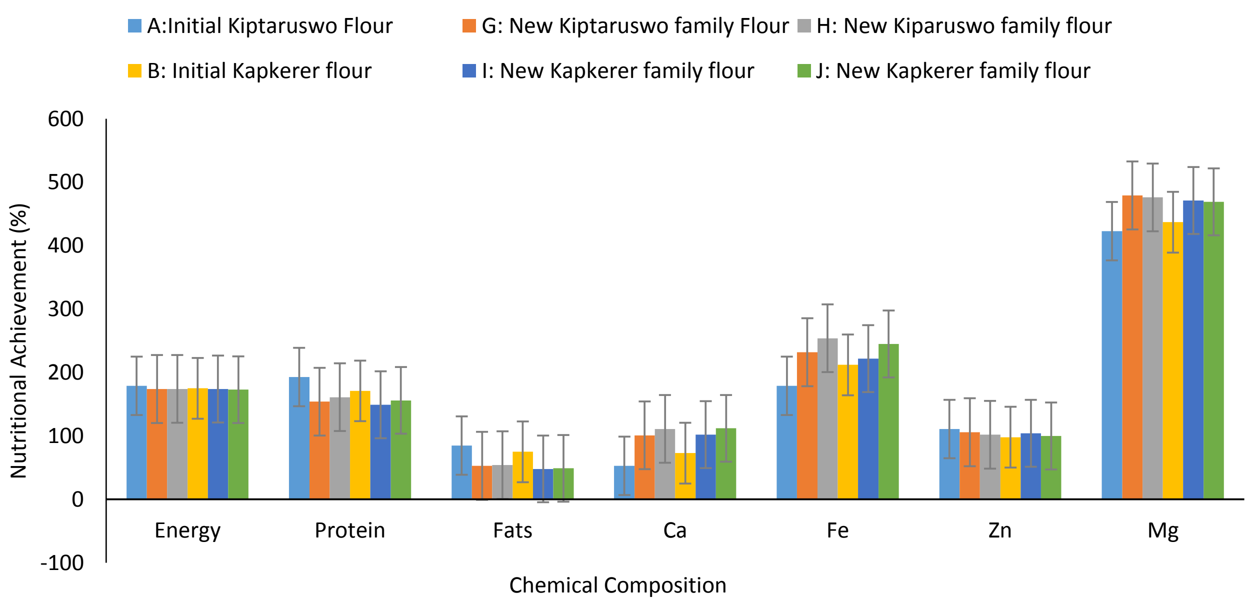

Figure 4.2: Percent achievement of the targeted nutrients in a composite porridge flour targeting a family set up.

The bars indicate the standard error of means.

During formulations of the new composite flours (C, D, E, F, G, H, I and J), 100% achievement of the respective RDA for each nutrient expect fats which was intentionally reduced was achieved. This aimed at improving the shelf life of the new formulations against fats oxidation believed to have been the main safety and quality degradation process of the flours while improving on the nutritional status of the former formulations (A and B). RDA for the fats, calcium and zinc were the only ones not met by the initial formulations (A and B).

Table 4.1: Legume-cereal-root based flour formulation for family and school going children/kg

		Formulations[*2]									
		Initial formulations		**New Formulations**		**Children**		**New Family**		**Formulations**	
		Kapkerer	**Kiptaruswo**	**Kapkerer**		**Kiptaruswo**		**Kapkerer**		**Kiptaruswo**	
	Price / kg[*1]	**B**	**A**	**E**	**F**	**C**	**D**	**I**	**J**	**G**	**H**
Ingredients											
Maize	40	39	43	0	0	0	0	35	35	35	35
Millet	100	16	6	37	32	35	40	30	35	30	35
Pumkin seed	125	0	2	0	0	1	1	0	0	1	1
Arrowroot	75	0	6	0	0	0	0	0	0	0	0
Buckwheat	125	0	3	0	0	0	0	0	0	0	0
Wheat	75	0	6	0	0	0	0	0	0	0	0
Groundnut	130	3	3	0	0	0	0	1	1	1	1
Amaranth seed	150	0	1	1	1	1	1	0	0	0	0
Cassava	50	13	12	37	37	38	43	28	23	27	22
Lablab	100	7	6	0	0	0	0	1	1	1	1
Soybean	75	3	6	15	10	10	10	3	3	3	3
Sorghum	50	19	6	10	20	15	5	2	2	2	2
Total (%)		**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
Buying Price / Kg (Kes)	**61**	**63**	**73**	**70**	**72**	**72**	**64**	**66**	**64**	**67**	

[*1]The price indicated is the buying price per kg of either ingredient or composite flour. [*2]A-Kiptarusow's Farmers group initial formulation, B-Kapkerer's Farmers group initial formulation, C & D-New Kiptaruswo's Farmers group children flour formulation, E & F- New Kapkerer's Farmers group children flour formulation, G& H- New Kiptaruswo's Farmers group family flour formulation and I & J- New Kapkerer's Farmers group family flour formulation.

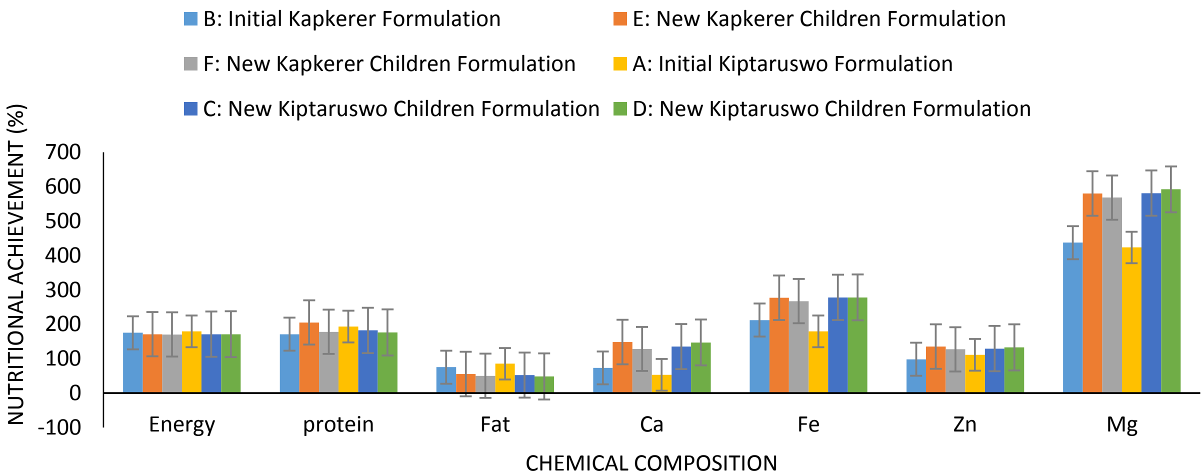

Figure 4.3: Percent achievement of nutrient in composite porridge flour targeting primary school going children.

***The bars indicate the standard error of means.**

Similar nutrient dense product formulation utilizing locally available ingredients while optimizing on their process and acceptability have been done (Kunyanga *et al*., 2012; Ndagire *et al*., 2015). Therefore, knowledge on the chemical composition of each ingredients was effective on nutritional improvement of the former formulations

4.3.2 Process Optimization

4.3.2.1 Effect of Soaking Finger Millet on Phytate and Tannins Content

Table 4.2 shows effect of soaking finger millet on phytate and tannins content (g/100 g). Un-soaked finger millet had phytate content of 0.60g/100g. Higher values of 851.6 to 1419.4mg/100g in finger millet and 747mg/100g in pearl millet were reported by Makokha *et al*., (2002) and Osman, (2011) respectively.

Soaking finger millet in-significantly ($p>0.05$) increased phytate content by 21-34% regardless of the soaking sample to water ratio and soaking duration. Millet is among the cereals with low phytase activity which is further reduced by soaking due to leaching of the phytase from the aleurone layer (Egli *et al.*, 2002). More so, seed coats were lost during rinsing or changing of the soaking water leaving the aleurone layer where phytate are more concentrated (Egli *et al.*, 2002).This may explain the increase on phytate observed in finger millet. This is consistent with the findings of Embaby, (2010) and Wang *et al.*, (2008) after de-hulling lupin seeds and field peas respectively.

Un-soaked finger millet had tannins content of 0.82g/100 g (Table 4.2) but reduced by 67-85% through soaking. Tannins lost in all soaking treatments of finger millet, were significantly ($p<0.05$) different from the control though percentage reduction in all treatments were in close range with no significant ($p>0.05$) difference between them.

Highest percentage loss of tannins in finger millet was at 24 hrs of soaking in all soaking ratios. Amount of tannins found in finger millet were much higher than 0.27mg/100g reported by Mbithi-Mwikya *et al.,* (2000) and 0.989mg/kg by Abubakar *et al*., (2015). Tannins are concentrated on the seed coat (Pastuszewska *et al*., 2004; Chukwumah *et al.*, 2007; Rocha-Guzman *et al.,* 2007) which was lost in between rinsing after the soaking hours. This may explain the high loss of tannins in soaked finger millet.

Table 4.2: Effect of soaking finger millet on phytate (g/100g) and tannins (g/100g) content

Treatments		Anti-nutrient*	
		Phytate	***Tannins***
Control		0.60 ± 0.02^{a}	0.82 ± 0.89^{a}
Soaking ratio	Soaking hours		
1:1	6	0.74 ± 0.08^{a} (+22)	0.18 ± 0.01^{b} (-78)
	12	0.72 ± 0.03^{a} (+21)	0.18 ± 0.05^{b} (-78)
	24	0.80 ± 0.06^{a} (+34	0.17 ± 0.04^{b} (-79)
1:2	6	0.75 ± 0.02^{a} (+25)	0.17 ± 0.04^{b} (-79)
	12	0.73 ± 0.06^{a} (+23)	0.27 ± 0.01^{b} (-67)
	24	0.80 ± 0.02^{a} (+34)	0.13 ± 0.10^{b} (-84)
1:3	6	0.75 ± 0.09^{a} (+26)	0.16 ± 0.03^{b} (-80)
	12	0.73 ± 0.01^{a} (+22)	0.19 ± 0.01^{b} (-77)
	24	0.78 ± 0.07^{a} (+30)	0.12 ± 0.06^{b} (-85)

***Values in the same column followed by different superscript letters ($^{a/b}$) are significantly different at $p<0.05$.The values represent means and standard deviation (±) of duplicate analysis. Values in parenthesis indicate percentage increase (+) or decrease (-) from the control.**

4.3.2.2 Effect of Soaking and Roasting Groundnut on Phytate and Tannins Content

Table 4.3 shows effect of soaking and roasting groundnut on phytate and tannins content (g/100g). Control samples of groundnut had phytate content of 2.26g/100g close to 2.63g/100g reported by Embaby, (2011) but higher than 9.29-15.3mg/100 reported by Adegunwa *et al.*,

(2007) in groundnut. An average of 51 and 65-71% phytate was reduced by roasting un-soaked and soaked groundnut respectively.

Similar findings were reported by Udensi *et al.*, (2007) who reduced 52-62% phytate by roasting (120^{0}C for 30-120mins) cowpea while Adegunwa *et al.*, (2014) reduced 4% and 24% by roasting (110^{0}C for 15mins) and soaking (12 hrs) groundnut respectively. Although insignificantly different (p>0.05), higher percentage reduction of phytate in groundnut was noticed in samples soaked in either 1:2 or 1:3 soaking ratio regardless of soaking hours through leaching (Lestienne *et al.,* 2005; Afify *et al*., 2011). However, lesser percentage loss from 6 hrs of soaking was noticed at twelve hours of soaking in 1:1 and 1:2 soaking ratio before the soaking water was changed attributable to reabsorption of leached phytate (Xu and Chang, 2008).

Groundnut had tannins content of 1.09g/100g (Table 4.3) higher than 0.3-0.9mg/100g reported by Adegunwa *et al.*, (2007) and 0.09 mg/100g by Ejigui *et al.*, (2005). Apart from the 12 hrs of soaking, other soaking treatments significantly (p<0.05) reduced tannins by 26-49%. Soaking groundnut for 12 hrs insignificantly (p>0.05) increased retained tannins from as at 6 hrs of soaking with the highest increase being in 1:1 and 1:2 soaking ratios. The increase may be attributed to reabsorption of the leached tannins from the soaking water (Xu and Chang, 2008). However, continued soaking for additional 12 hrs reduced the tannins content but not below the levels obtained with soaking for 6 hrs. Roasting un-soaked groundnut significantly (p<0.05) increased tannins by 12% compared to the control.

Tannins increase after roasting un-soaked groundnut contradicts Adegunwa *et al*., (2014) findings of reducing tannins from 0.96 to 0.71mg/100g. The decrease in tannins content during roasting could be due to thermal degradation (Xu and Chang, 2008; Khandelwal *et al.,* 2010) while the increase maybe as a result of their hydrolysis (Osman, 2011).

Table 4.3: Effect of soaking and roasting groundnut on phytate (g/100g) and tannins (g/100g)

Samples		Anti-nutrients*	
		Phytate	**Tannins**
Control		2.26±0.75[a]	1.09±0.02[bc]
Un-soaked		1.10±0.01[b] (-51)	1.21±0.05[a] (+12)
Soaking ratio	**Soaking Hours**		
1:1	6	0.75±0.12[b] (-67)	0.61±0.01[f] (-44)
	12	0.79±0.16[b] (-65)	1.10±0.02[b] (+1)
	24	0.78±0.11[b] (-66)	0.81±0.02[d] (-26)
1:2	6	0.68±.03[b] (-70)	0.56±0.04[f] (-49)
	12	0.80±0.30[b] (-65)	1.11±0.02[b] (+2)
	24	0.81±0.08[b] (-64)	0.75±0.02[de] (-31)
1:3	6	0.71±0.11[b] (-69)	0.72±0.01[e] (-34)
	12	0.66±0.06[b] (-71)	1.04±0.03[c] (-4)
	24	0.67±0.02[b] (-70)	0.80±0.01[d] (-27)

***Values in the same column followed by different superscript letters ([a, b c, d, e, f]) are significantly different at p<0.05.The values represent means and standard deviation (±) of duplicate analysis. Values in parenthesis indicate percentage increase (+) or decrease (-) from the control.**

4.3.2.3 Effect of Soaking and Roasting Soybean on Phytate and Tannins Content

Control samples of soybean had phytate content of 1.06g/100g (Table 4.4). Phytate values observed were within the range of 0.801 to 1.188g/100 reported in peas and kidney beans by Khattab and Arntfield, (2009).

Roasting un-soaked soybean reduced phytate content by 34% while combined soaking and roasting reduced phytate by 24-44%. Khattab and Arntfield, (2009) similarly reduced 36-48%% phytate by roasting (180^{0}C for 15-20mins) kidney beans.

Phytate in all treated soybean, significantly reduced ($p<0.05$) from the control. There was lesser percentage reduction in phytate at 12 hrs of soaking from as at 6 hrs although, prolonged soaking (24 hrs) however, further reduced phytate but not as low as at 6 hrs. Unlike in groundnut, highest phytate reduction in soybean regardless of the soaking hours was observed in 1:1 soaking ratio. Soybean is one of the legumes with high phytase activity (Egli *et al*., 2002). Besides its high phytase activity, the observed high hydration rate limited leaching of other components (Siddhuraju and Becker, 2001) that forms insoluble complexes with phytate upon heating (Elhardallou and Walker, 1994; Siddhuraju and Becker, 2001; Udensi *et al.*, 2007). This explains high phytate reduction at lower soaking ratio in soybean.

Tannins content of 1.56 g/100g (Table 4. 4) were found in untreated soybean. Soaking and roasting significantly reduced tannins by 50-76%. Roasting without soaking of soybean was shown to reduce tannins by 75%. In all soaking ratios, soaking beyond 6 hours resulted in lesser tannins reduction. Highest tannins reduction was in 1:3 soaking ratio at all soaking hours. Leaching in soaking water (Xu and Chang, 2008) plus thermal degradation (Xu and Chang, 2008; Khandelwal *et al.*, 2010) during roasting explains the decline in tannins.

Table 4.4: Effect of soaking and roasting soybean on phytate and tannins (g/100g) content.

Samples		**Anti-nutrients***	
		Phytate	Tannins
Control		1.06±0.10[a]	1.56±0.54[a]
Un-soaked		0.69±0.10[bc] (-34)	0.40±0.25[c] (-75)
Soaking ratio	**Soaking hours**		
1:1	6	0.60±0.03[c] (-44)	0.45±0.04[bc] (-71)
	12	0.64±0.05[bc] (-40)	0.60±0.01[bc] (-62)
	24	0.62±0.14[bc] (-41)	0.78±0.01[b] (-50)
1:2	6	0.65±0.06[bc] (-39)	0.47±0.05[bc] (-70)
	12	0.69±0.08[bc] (-35)	0.65±0.02[bc] (-58)
	24	0.66±0.04[bc] (-37)	0.78±0.02[b] (-50)
1:3	6	0.77±0.16[bc] (-27)	0.38±0.01[c] (-76)
	12	0.80±0.10[b] (-24)	0.54±0.06[bc] (-65)
	24	0.62±0.01[bc] (-42)	0.58±0.05[bc] (-63)

***Values in the same column followed by different superscript letters ([a, b, c]) are significantly different (p<0.05). The values represent means and standard deviation (±) of duplicate analysis. Values in parenthesis indicate percentage increase (+) or decrease (-) from the control.**

4.3.2.4 Effect of Soaking and Boiling Lablab on Phytate and Tannins Content

Lablab had phytate content of 0.840/100g (Table 4.5). Huma *et al*., (2008) reported much lesser values in legumes (233.33 to 599.67mg/100g). Soaking resulted to significant ($p<0.05$) loss of 14-26% phytate with higher loss being in higher soaking ratio (1:2/ 1:3) at all soaking hours. Highest phytate loss was after 24 hrs of soaking regardless of the soaking ratio.

Table 4.5: Effect of soaking and boiling lablab on phytate content (g/100g)

Soaking ratio	Soaking hours	Boiling time (Minutes) *		
		0	30	60
Control		0.84±0.13 [a]	1.04±0.02[b] (+24)	1.02±0.04[b] (+21)
1:1	6	0.71±0.03[d] (-15)	1.03±0.01[b] (+23)	1.00±0.05[bc] (+19)
	12	0.72±0.05[d] (-14)	0.97±0.01[bc] (+15)	0.95±0.01[bc] (+13)
	24	0.70± 0.01[d] (-17)	0.94+0.02[c] (+12)	0.92±0.05[c] (+10)
1:2	6	0.68±0.08[e] (-19)	0.99±0.01[b] (+17)	0.97± 0.20[bc] (+15)
	12	0.69±0.05[e] (-18)	0.97±0.02[bc] (+15)	0.90±0.03[cd] (+7)
	24	0.65±0.02[e] (-22)	0.93±0.01[bcd] (+10)	0.87±0.07[d] (+4)
1:3	6	0.64±0.02[c] (-24)	0.94±0.01[b] (+12)	0.93±0.03[ab] (+10)
	12	0.65±0.03[c] (-23)	0.89±0.01[ab] (+6)	0.87±0.03[ab] (+4)
	24	0.62±0.01[c] (-26)	0.89±0.04[ab] (+6)	0.86±0.08[ab] (+2)

***Values in the same soaking ratio followed by different superscript letters (a, b, c, d) are significantly different at $p<0.05$.The values represent means and standard deviation (±) of duplicate analysis. Values in parenthesis indicate percentage increase (+) or decrease (-) from the control.**

Endogenous Phytase enzyme (*myo*-inositol hexakisphosphate phosphohydrolase) (Egli *et al.*, 2002) upon soaking is activated to breakdown IP6 to lower molecular weight inositols phosphates i.e myo-inositol penta (IP5), tetra (IP4), tri (IP3), di (IP2) and mono (IP1) phosphate (Skoglund, *et al.*, 1998) whose solubility in the soaking medium increases with decrease in the phosphate groups (Phillippy *et al*., 1988; Siddhuraju and Becker, 2001). This explain the increased reduction of phytate during soaking of also groundnut and soybean. However, similar to soybean and groundnut, there was reabsorption (Xu and Chang, 2008) of leached phytate resulting in lower percentage loss of phytate at 12 hrs of soaking in 1:1 and 1:2 soaking ratio compared to 6 hrs of soaking. Phytate reduction after soaking contradicted Embaby, (2010) findings of 1.5% increase in bitter lupin and 13.6% in sweet lupin after soaking (24 hrs) and Lestienne *et al.*, (2005) findings of 4% increase after soaking (24 hrs) cowpea. Compared with the control, boiling for 30 and 60mins resulted in 6-24% and 2-21 % increase in phytate respectively. This was contrary to; Udensi, *et al.*, (2007) findings of reducing 32-68% phytate by boiling (15-60mins) cowpea; Khattab and Arntfield, (2009) findings of reducing 58% phytate after boiling kidney beans and Adegunwa *et al*., (2014) 26% phytate reduction after boiling(60mins) groundnut. However, regardless of soaking ratio and time, prolonged boiling (60mins) reduced the amount of retained phytate compared to 30mins of boiling.

During heating, IP6 which is heat labile (Udensi *et al*., 2007) is broken down to lower molecular weight inositols (Siddhuraju and Becker, 2001; Frontela *et al*., 2008; Martín-Cabrejas *et al*., 2009) which though not harmful (Kozlowska *et al.,* 1996) were undifferentiated by the methodology used (Phillippy *et al.*,1988) resulting in reporting of higher values of phytate (Schlemmer *et al*., 2009). This could have been the case in lablab where leaching in the boiling water may not have been effective to reduce phytate content though prolonged boiling (60mins) showed further phytate loss from 30mins of boiling. Similar increase in phytate after boiling lablab were found by Wang *et al*., (2008) who reported 8% increase after cooking field peas and Frontela *et al*., (2008) who found 5% increase of IP5 after roasting mult cereals.

Untreated lablab had 0.58g/100g tannins (Table 4.6). Soaking of lablab resulted in 13-25% reduction of tannins while boiling for 30 or 60mins further reduced tannins by 38-91% and 50-87% respectively. Apart from the 1:1 soaking ratio where in-significant ($p>0.05$) changes were observed, other soaking hours (12 and 24 hrs) significantly ($p<0.05$) decreased tannins. Lablab significantly ($p<0.05$) reduced tannins in all samples (soaked and un-soaked) with highest loss being in 60mins boil.

Similar increase in tannins after soaking (in 1:1 and 1:2 at 6 hrs of soaking) was found by Xu and Chang, (2008) after soaking peas. The increase may have been as a result of breakdown of insoluble high molecular weight polymers to soluble low molecular weight polymers or reabsorption from the soaking water (Osman, 2007). Increased tannins reduction by cooking lablab were consistent with those found by; Salariya, (2005) who reduced 24-26% tannins in cooked kidney beans and Udens *et al.*, (2007) who reduced 75% tannins in cowpea after cooking.

Leaching in soaking and boiling (Xu and Chang, 2008) water plus thermal degradation (Egli *et al.*, 2002; Xu and Chang, 2008) during boiling explains tannins reduction. Reduction of phytate and tannins would not only result in improvement of protein and starch digestibility of finger millet, groundnut, soybean and lablab (Rehman and Shah, 2005; Martín-Cabrejas et a*l*., 2009; Ndagire *et al*., 2015) but also on minerals bioavailability (Lestienne *et al.*, 2005; Afify *et al.*, 2011;). Since phytate and tannins reduction wasn't to a 100%, the residues would be beneficial in; acting as antioxidant hence extend shelf life in groundnut and soybean flour (Adegunwa *et al.,* 2014)), reduction of diabetes mellitus (Bouchenak, 2013) and cardiovascular diseases (Marventano, 2016) incidences to their consumers. Hence the nutritional quality of the products will have been enhanced.

Table 4.6: Effect of soaking and boiling lablab bean on tannins (g/100g) content

Soaking ratio	Soaking hours	Boiling time (Minutes) *		
		0	30	60
Control		0.58±0.03[a]	0.31±0.02b (-48)	0.14±0.01[c] (-76)
1:1	6	0.69±0.05[b] (+19)	0.36±0.22[d] (-38)	0.23±0.02[e] (-61)
	12	0.49±0.01[c] (-16)	0.16±0.03[ef] (-73)	0.10±0.06[f] (-84)
	24	0.48±0.01[c] (-18)	0.14±0.01[ef] (-76)	0.11±0.11[f] (-81)
1:2	6	0.67±0.06[a] (+15)	0.30±0.02[c] (-48)	0.14±0.06[d] (-76)
	12	0.51±0.16[b] (-13)	0.16±0.01[d] (-72)	0.10±0.25[d] (-83)
	24	0.49±0.02[d] (-16)	0.28±0.01[c] (-52)	0.07±0.01[d] (-87)
1:3	6	0.49±0.09[b] (-17)	0.30±0.01[c] (-49)	0.29±0.11[c] (-50)
	12	0.44±0.09[b] (-24)	0.17±0.36[d] (-71)	0.09±0.04[de] (-85)
	24	0.44±0.06[b] (-25)	0.05±0.03[e] (-91)	0.08±0.02[de] (-87)

***Values in the same soaking ratio followed by different superscript letters (a, b, c, d, e, and f) are significantly different at $p<0.05$.The values represent means and standard deviation (±) of duplicate analysis. Values in parenthesis indicate percentage increase (+) or decrease (-) from the control.**

4.3.3 Chemical Composition

4.3.3.1 Proximate Composition

Table 4.7 shows proximate composition of all ingredients in this study. Legumes, cereals, pseudo cereals and roots had lowest and highest moisture content (%) of; 1.71 and 10.00, 6.71 and 10.51, 1.41 and 10.26, 4.44 and 5.67 respectively. Pumpkin seed and groundnut contained significantly ($p<0.05$) lowest moisture (%) at 1.41 and 1.71 respectively but also contained the highest fat (%) content at 38.14 and 46.29 respectively. This was ideal in enabling grinding of individual grains and keeping quality of the flour (Elinge *et al*., 2012). Significantly ($p<0.05$) highest moisture content (%) found in Lablab (10.00), buckwheat (10.26) and finger millet (10.51) were however lower than the maximum allowable moisture content (≈15.5% or 13.5%) (Eeast African Standard, 2012; Standard, 1995). Thus, the shelf life of the formulated composite flours would not be compromised.

Fat content (%) were significantly ($p<0.05$) lowest in cassava (0.50), arrowroot (0.55), buckwheat (1.47) and finger millet (2.25) but highest in Soybean (14.85), pumpkin seed (38.14) and groundnut (46.29). Fat content (%) among cereals and roots were insignificantly ($p>0.05$) different from each other unlike among legumes and pseudo cereals whose content were significantly different ($p<0.05$). Thus, since the study aimed at reducing total fats in formulated composite flour, proportional reduction of legumes and pseudo cereals but an increase in cereals and roots would help achieved this objective. Fat content (%) in sorghum (4.92) was within the range of 1.6-5.0 and 2.1-7.6 reported by Queiroz *et al*., (2015) and International Crops Research Institute for Semi-Arid Tropics (ICRISAT) and Food Agricultural Organization (FAO) (1996) respectively. Lower values (1.24 -3.0%) were reported by Martino *et al.*, (2012) in sorghum genotypes produced in brazil. Similar fat content (%) found in amaranth seed , soybean and groundnut were reported by Hammond, (2005), Alvarez-jubete *et al.*, (2009) and Ayoola *et al.*,*(*2012), respectively. However, higher fat (%) values in amaranth seed were reported by Pedersen *et al.*, (1987) (9.5-10.9%) and Erum *et al*., (2012) (≈15-28%).

Legumes are considered as poor man's meat due to the high protein content (Bello-Perez *et. al.*, 2007). This was consistent with the high protein content (percentage) found in soybean (41.14) and groundnut (32.22) although slightly lower protein values were found in lablab (10.06) in comparison to some cereals and pseudo cereals. High moisture content and geographical location could have been the reason for the low protein (%) content found in lablab although higher values (21.34-22.3) were reported by Kalpanadevi and Mohan, (2013). Comparatively to legumes, pumpkin seed contained high protein levels (34.88) while arrowroot contained the least (5.98). Similar, high protein content (%) in buckwheat (12.08) and amaranth seed (9.78) been reported by Alvarez-Jubete *et al.*, (2009) (12.5) and Ikeda *et al*. (2005) 16.5) respectively. Therefore, arrowroot, cassava, maize, amaranth seed and sorghum are not considerable good sources of protein.

High fibre consumption in the diet is beneficial to health (Champ *et al*., 2003; Elinge *et al.*, 2012). Pseudo-cereals are considerable good sources of fibre (Alvarez-Jubete *et al*., 2010). This was consistent with high fibre content (%) in buckwheat (13.48) and pumpkin seed (13.70) found in comparison to legumes, cereals and roots. However, lower fibre content in pumpkin seed (1%) have been reported by Elinge *et al.*, (2012). Despite groundnut having the largest seed coat than most grains, its flour had significantly ($p<0.05$) lowest fiber content among legumes. This was as a result of its big surface area to volume ratio in comparison to other grains.

Lowest fibre content (%) were found in Cassava (2.66) and arrowroot (2.17) thus had the finest flour therefore making them the poorest sources of fibre while pumpkin seed, buckwheat, lablab and soybean as the best fibre sources.

Ash content (%) is relatively proportional to the mineral content of the sample and geographical location of its growth (Elinge *et al.*, 2012; Kachiguma *et al.*, 2015). Legumes had significantly ($p<0.05$) high ash content (2.41-5.04%) followed by pseudo cereals (2.33-3.99%), cereals (1.09-

2.74%) and roots (0.92-1.59%) in descending order. Thus legumes were the best ash sources while the roots were the poorest.

However, pseudo-cereals had comparable ash content to legumes ($p>0.05$). Ash content of 4.01-4.26 % found by Kalpanadevi and Mohan, (2013) in lablab were close to what was observed in soybean and lablab while Kachiguma *et al*., (2015) found averagely higher ash content in amaranth varieties (4.41-8.73%). Therefore, lablab, soybean and pumpkin seed were the best mineral sources while arrowroot, maize, cassava and wheat were the poorest.

Roots had the highest carbohydrate content while pumpkin seed, groundnut and soybean had the least. Grains with high fat content proportionally had high-energy content. This was evident in significantly ($p<0.05$) high-energy values found in wheat, soybean, pumpkin seed and groundnut. Thus cereals can be considered as potential carbohydrates sources while high fat containing grains as energy sources *(*Elinge *et al*., 2012).

Table 4.7: Proximate composition of ingredients used in porridge composite flour development

Sample	Sample Classification	Moisture (%)	Fat (%)	Protein (%)	Fibre (%)	Ash (%)	CHO (%)	Energy (Kcal/100g)
Lablab	*Legume*	10.00 ± 0.01^{f}	5.87 ± 2.11^{d}	10.06 ± 1.20^{c}	9.61 ± 0.33^{g}	3.9 ± 0.09^{f}	60.56 ± 2.22^{d}	335.31 ± 2.35^{b}
Soybean	*Legume*	4.28 ± 0.02^{b}	14.85 ± 0.49^{e}	41.14 ± 1.53^{h}	12.51 ± 0.05^{h}	5.04 ± 0.08^{g}	22.18 ± 3.25^{c}	386.93 ± 1.65^{i}
Groundnut	*Legume*	1.71 ± 0.15^{a}	46.29 ± 0.16^{g}	32.22 ± 0.29^{f}	8.07 ± 1.05^{f}	2.41 ± 0.10^{cde}	9.30 ± 1.22^{b}	582.69 ± 2.33^{k}
Wheat	*Cereal*	7.48 ± 0.30^{d}	4.45 ± 2.90^{cd}	12.07 ± 0.04^{e}	3.48 ± 0.25^{b}	1.38 ± 0.07^{ab}	71.14 ± 5.20^{h}	372.89 ± 0.57^{h}
Sorghum	*Cereal*	6.71 ± 0.87^{d}	4.92 ± 2.05^{cd}	9.91 ± 0.08^{c}	6.85 ± 1.46^{e}	2.22 ± 0.21^{bcd}	69.39 ± 1.50^{g}	361.48 ± 5.23^{e}
Finger millet	*Cereal*	10.51 ± 0.94^{f}	2.25 ± 0.14^{abc}	11.04 ± 0.05^{d}	5.35 ± 0.14^{d}	2.74 ± 0.07^{de}	68.11 ± 1.53^{f}	336.85 ± 1.71^{c}
Maize	*Cereal*	8.64 ± 0.02^{e}	4.02 ± 0.01^{bcd}	8.70 ± 0.27^{b}	4.28 ± 0.06^{c}	1.09 ± 0.08^{a}	73.27 ± 0.02^{i}	364.06 ± 6.67^{f}
Buckwheat	*Pseudo-cereal*	10.26 ± 0.67^{f}	1.47 ± 0.09^{ab}	12.08 ± 0.82^{e}	13.48 ± 0.52^{i}	2.33 ± 0.20^{cde}	60.38 ± 0.10^{d}	303.07 ± 1.08^{a}
Amaranth seed	*Pseudo-cereal*	8.37 ± 0.56^{e}	5.70 ± 1.11^{d}	9.78 ± 0.11^{c}	7.54 ± 0.29^{f}	2.95 ± 0.10^{e}	65.66 ± 1.20^{e}	353.06±2.01d
Pumpkin seed	*Pseudo-cereal*	1.41 ± 0.02^{a}	38.14 ± 0.65^{f}	34.88 ± 0.37^{g}	13.70 ± 0.03^{i}	3.99 ± 0.10^{f}	7.88 ± 0.56^{a}	514.30 ± 4.07^{j}
Cassava	*Roots*	4.44 ± 0.12^{b}	0.50 ± 0.02^{a}	9.66 ± 0.07^{c}	2.66 ± 0.04^{a}	1.59 ± 0.23^{abc}	81.15 ± 3.44^{j}	367.74 ± 6.89^{g}
Arrowroot	*Roots*	5.67 ± 0.04^{c}	0.55 ± 0.48^{a}	5.98 ± 0.10^{a}	2.17 ± 0.19^{a}	0.92 ± 0.10^{a}	84.71 ± 0.74^{k}	367.71 ± 1.58^{g}

The values are a mean of two analysis ± standard deviation per 100g. Values followed by different superscript letters along the column are significantly different at P<0.05

4.3.3.2 Mineral Composition

Table 4.8 shows mineral content (mg/100g) of each ingredient. Varying zinc content (mg/100g) ranges were found in legumes (0.58-2.53), cereals (0.75-0.85), pseudo cereal (2.60-3.25) and roots (1.57) respectively. Calcium levels (mg/100g) were significantly different ($p<0.05$) across all ingredients. Among the legumes, cereals and pseudo cereals, highest calcium levels (mg/100g)

were found in soybean (201.00), finger millet (257.50) and amaranth seed (136.00) respectively. Maize (6.65mg/100g) had the least calcium levels while finger millet had the highest. Though significantly different ($p<0.05$), all grains had high magnesium levels (mg/100g) except maize (80) which had less than 100mg/100g while pumpkin seed had the highest (416.00). Significantly high ($p<0.05$) iron content (mg/100g) was found in Pumpkin seed (31.00) followed by amaranth seed (16.00) and finger millet (15.00) while cassava (1.50) had the least amount. Amount of iron (mg/100g) found in sorghum (8.50) and finger millet was comparable ($p>0.05$) to that found in soybean (8.00) and amaranth seed respectively. Amount of zinc (mg/100g) found in lablab are in close range of 1.96- 2.24 mg/100 g found by (Kalpanadevi and Mohan, 2013).

Pseudo-cereals are known to be good sources of minerals (Alvarez-Jubete *et al.*, 2010) this is consistent with the high mineral values found in respective grains. Averagely lower values of zinc (0.9 mg/100g), magnesium (65.87 mg/100g) and iron (12.23 mg/100g) but higher calcium (370.3mg/100g) levels in amaranth seed were reported by Kachiguma *et al*., (2015) however Pedersen, *et al*.,(1987) and Mnkeni *et al*., (2007) found varying ranges of the same. Higher zinc (4.18 mg/100g) and magnesium (220 mg/100g), similar calcium(201 mg/100g) but lower iron (6.64 mg/100g) content in soybean were reported by Fachmann *et al*., (2000). Thus soybean, finger millet, amaranth seed and pumpkin seed are the best mineral sources.

Table 4.8: Minerals (mg/100g) composition of ingredients used in porridge flour

Sample	Classification	Zinc	Calcium	Magnesium	iron
Lablab	Legume	1.50 ± 0.22^{ab}	106.00 ± 0.05^{f}	165.00 ± 0.03^{d}	5.50 ± 0.75^{c}
Soybean	Legume	2.53 ± 0.15^{cd}	201.00 ± 0.89^{h}	195.00 ± 0.65^{g}	8.00 ± 0.03^{d}
Groundnut	Legume	0.58 ± 0.06^{a}	98.00 ± 0.57^{e}	171.00 ± 1.03^{e}	5.80 ± 0.05^{c}
Sorghum	Cereal	0.85 ± 0.14^{ab}	34.00 ± 0.95^{c}	142.00 ± 0.89^{b}	8.50 ± 0.56^{d}
Finger millet	Cereal	0.75 ± 0.33^{ab}	257.50 ± 0.39^{i}	$168\pm1.06d^{e}$	15.00 ± 0.27^{e}
Maize	Cereal	0.75 ± 0.43^{ab}	6.65 ± 0.89^{a}	80.00 ± 2.03^{a}	3.50 ± 0.06^{b}
Amaranth seed	Pseudo-cereal	2.60 ± 0.03^{d}	136.00 ± 0.56^{g}	149.00 ± 0.99^{c}	16.00 ± 0.01^{e}
Pumpkin seed	Pseudo-cereal	3.25 ± 0.06^{d}	14.00 ± 0.45^{b}	416.00 ± 0.78^{h}	31.00 ± 0.36^{f}
Cassava	Root	1.57 ± 0.67^{bc}	47.33 ± 0.76^{d}	181.50 ± 1.05^{f}	1.50 ± 0.50^{a}

The values represent means of duplicate analysis. ± is standard deviation of two analysis. Values followed by different superscript letters along the column are significantly different at p=0.05.

CHAPTER FIVE: SENSORY QUALITY, NUTRITIONAL AND ANTI-NUTRITIONAL COMPOSITION OF OPTIMIZED LEGUME BASED PORRIDGES

ABSTRACT

Most porridges are prepared from cereals and consumed as either a beverage or a weaning food. However, malnutrition among children has necessitated inclusion of legumes and roots in an effort to boost nutrient and energy density. Therefore, the current study aimed at identifying the most acceptable porridge based on different food ingredients combination and nutritional composition of the most acceptable porridge. Composite porridge flour included legumes (soybean, groundnut, and lablab), cereals (finger millet, sorghum, maize and wheat), pseudo cereals (pumpkin seed, buckwheat and amaranth seed) and roots (cassava and arrowroot). New composite porridge flours were formulated using Nutri survey mult-linear programming software. Different composite flours formulated were subjected to consumer preference test and sensory analysis.

The new formulations targeted primary school-going children and a family set up. Participants (149) composed of men (30.9%) and women (69.1%) aged from 11 to >60yrs were interviewed. Newly formulated porridges were preferred to the previous porridge formulations on; color (40-54.2%), smell (40-52.4%), taste (41.5-47.5%), texture (58.3%), viscosity (35.4-45.8%) and overall acceptability (35-54.2%). The most cited reason for liking or disliking a particular porridge was taste (38.9%) and texture (32.2%), respectively. However all the sensory attributes positively correlated with overall acceptability. The most acceptable porridge had varying chemical values per 100g; 7.19-16.54% protein, 2.82-4.34% fat, 2.75-3.61% fibre, 1.76-2.36% ash, 73.16-84.38% carbohydrates, 391.7-400Kcal energy, 7.63-13.87 mg/100g Mn, 25-

258.6mg/100g Ca, 3.42-4.21mg/100g Fe, 662.30-1190mg/100g K, 1.62-2.36mg/100g Cu, 0.68-3.34mg/100g Na, 120.70-194.80 mg/100g Mg and 2.54-3.08mg/100g Zn. More so, there was significant ($p<0.05$) reduction of phytates and tannins from their control. Therefore, optimization processes selected were effective in anti-nutrients reduction, locally available ingredients are adequate in supplying nutritional requirements of the target groups and satisfaction of consumer sensory attributes is key in product acceptability.

5.1 INTRODUCTION

All people need a diversity of food in order to meet their daily requirements (WFP,2016). However, this is has been a challenge especially among poor populations in the developing world whose diet are starch based with hardly any animal product or fruit. This is critical to vulnerable infants and children who need more nutritious foods for their growth and mental development for a healthy life (Arimond and Ruel 2004). This has as a result encouraged advocacy for dietary diversity. In an effort to curb malnutrition among vulnerable consumers, different flour processing and food fortification methods have been studied (Kunyanga *et al.*, 2012; Macharia-Mutie *et al.,* 2012; Onyango *et al., 2003*).

Food based interventions have been applied to reduce malnutrition and nutrition insecurity in Kenyan households (Abate and Orr, 2012; WFP,2016). Porridge is popular in Kenya especially in rural areas and among low income earners in urban areas mostly made up of maize or cassava fortified with sorghum or finger millet (Onyango *et al., 2003*). Thus most consumed porridges are starch based and hardly meet nutritional requirements. However new ingredients like legumes and different roots and tubers are being introduced aiming at nutritional improvement (Kunyanga *et al.,* 2012; Tortoe *et al.* 2014; Ndagire *et al*., 2015).

Adults take porridge as a beverage while to children it is a major weaning food (Kikafunda, *et al*., 2006). However, its consumption is being threatened by quick to make beverages like tea or coffee especially among middle and upper income earners (Onyango *et al., 2003)*. Porridge is prepared by boiling fermented or non-fermented flour (Van der Merwe, *et al*., 2001; Kikafunda, *et al.*, 2006; Macharia-Mutie *et al.*, 2012; Ndagire *et al.*, 2015) with water to the desired consistency and sweetened with cane sugar before drinking.

Consumer acceptability is key (Kikafunda, *et al.*, 2006; Ndagire *et al.*, 2015) in adoption of new developed products. Undesirable sensory attributes of nutrient dense product may limit their nutrient and energy uptake by the target groups (Arimond and Ruel 2004) hence devaluing the effort of developing a nutritious product. Cooking, blending and processing have been utilized in developing nutrient and energy dense gruels especially for weaning children (Ndagire et al., 2015). Therefore, the current study aimed at identifying the most acceptable composite legume-based porridge for school going children and for a family set up.

5.2 METHODOLOGY

5.2.1 Sample Collection

Sample ingredients collected for formulation and analysis included; lablab (*Lablab purpureus*), soybean (*Glycine max)*, groundnut (*Arachis hypogaea)*, finger millet (*Eleusine coracana)*, sorghum (*Sorghum bicolor*), maize (Zea mays), wheat (*Triticum aestivum)*, buckwheat (*Fagopyrum esculemtum)*, amaranth seed (*Amaranthus*), pumpkin seed (*Cucurbita spp)*, arrowroot (*Marantha arundinaceae*) and cassava (*Manihot esculenta*). They were obtained from two farmers groups producing legume based porridge flour to economically empower their members and to mitigate malnutrition in children and vulnerable groups in Nandi County, Western Kenya. The farmer groups obtain the ingredients by purchasing from neighboring

Serem market Centre or from their fellow members and store them collectively in sacks. Respective ingredients stored in sacks were mixed before sampling 3kg of each, packaged separately and transported to food analysis laboratory at University of Nairobi for analysis.

5.2.2 Sample Preparation

Cleaning: All samples were sorted to remove spoilt seeds and graded for quality before wet cleaning and rinsing with tap water at ambient temperature.

Phytate and tannin reduction: This was selectively done to soybean, groundnut, finger millet and lablab. Soybean, groundnut and finger millet were soaked (at room temperature 22-25^{0}C) for 6 hours at sample to water ratio of 1:2 while lablab was soaked at 1:3 for 24 hours and boiled for 60 min. Dried groundnut and soybean were roasted for 10 min at 174 ± 2 ^{0}C in an air oven (Memmert, Germany). This was done according to process optimization study design findings (unpublished results).

Drying and roasting: Wet samples were oven dried at 64 ± 2^{0}C (Memmert, Germany) before further analysis.

5.2.3 Composite Flour Preparation

Two types of composite flour were developed; for school going children and for a whole family set up. Farmers groups had varying ingredients hence composite fours developed were different. Apportioning of each ingredient was based on findings from focused groups discussion (Unreported results) and nutritional profile of each ingredient. The formulations aimed at fulfilling Recommended Dietary Allowance (RDA) of an expectant mother (>4months expectant) by World Health Organization (WHO). Nutrisurvey Linear programming software was used in composite flour formulation. Formulations targeted achievement of 100% of all nutrients except for fats that was thought to cause flour spoilage by oxidation.

Ingredients were mixed, and ground using Black & Decker grinder and sieved through 600 μm for uniformity.

5.2.4 Porridge Preparation

Porridge was prepared by adding 250g of non-fermented composite flour in 400ml of cold water before adding to 450ml of boiling water. The mixture was brought to boil under continuous stirring then left to continually boil for additional 15 mins. The cooked gruel was immediately put in thermos flask to keep hot.

5.2.5 Chemical and Anti-Nutrients Analysis

Chemical and mineral analysis was done to the most acceptable porridge flour and their control only.

5.2.5.1 Proximate analysis

Samples moisture content was determined according to AOAC, (2008 method 967.08).

Kjeldahl method (AOAC, 2008 method 988.05) was used in protein analysis, total nitrogen was multiplied by factor 6.25.

Fat content were analyzed by soxhlet method (AOAC, 2008 method 2003.06).

Dietary fiber was determined by gravimetric method (AOAC, 2008 method 958.06).

Ash content was according to AOAC (2008 method 942.05).

Caloric value was determined by Wilwater conversion factor; Energy= 4 kcal /g (protein) + 9 kcal/g (fat) + 4 kcal/g (carbohydrates) based on Pearson, (1976) formula.

Carbohydrates were determined by the difference: Carbohydrates = [(% 100-(% protein+% fats+% moisture+% ash+% dietary fiber)].

5.2.5.2 Mineral Analysis

Samples were analyzed for iron, zinc, calcium and magnesium according to Puwastien *et al.*, (2011). To 0.5g sample, a mixture of conc. Nitric acid and hydrogen peroxide (5:3) was added and left to stand overnight in a fume chamber before digesting at 110^{0}C for 3 hrs or until a clear or milky digest was found. The digest was topped up to 50ml with deionized water for respective mineral analysis. Atomic Absorption Spectrophotometer (AAS) machine was used in the mineral analysis.

5.2.5.3 Phytates Analysis

Phytate were analyzed according to the method described by Latta and Eskin, (1980). A sample of 1g was defatted by adding 10ml of petroleum ether and left to stand for 2 hrs, decanted and let to dry. Hydrochloric acid (10ml at 2.4%) was added to the dried samples and centrifuged (Dr. Ngerber, K.Schneider & co, Zurich, Centrifuge) for 10mins at 482.97g. Centrifuging was repeated four times, each time the supernatant was collected in 100ml volumetric flask. Wade reagent (2ml mixture of 0.03 % Iron chloride and 0.3% sulfosalicyclic acid) was added to 2ml of sample solution and topped up to 10ml. Absorbance was read at 500nm (Single beam spectrophotometer, Milton Roy Company, Spectronic 1001, USA). Phytate content was calculated as g/100g using phytic acid standard curve prepared as described by Latta and Eskin, (1980).

5.2.5.4 Tannins Analysis

Tannins were analyzed as per AOAC (2012) 19th edition, method number 952.0 with modification. Follins denis reagents was prepared as per Ferreira et al., (2004). Approximately 0.5g sample was extracted with 50ml of distilled water, vortexed for 5mins and left to decant. Folins Denis reagent (2ml) was added to 75ml of distilled water followed by 2ml of sample solution and finally 5ml of concentrated sodium carbonate was added. The total mixture was topped up to 100ml, vortexed and left to stand for 40mins before reading absorbance at 725nm (Single beam spectrophotometer, Milton Roy Company, Spectronic 1001, USA).

5.2.6 Sensory Analysis

An informed verbal and written consent was obtained from each adult while for the school going children the head teacher of the school signed on their behalf before the start of the sensory analysis. Each farmers group had five types of porridges to be analyzed; two targeting school going children and two for a family set up plus the control. Each porridge category was analyzed on a different day. The participants included upper primary pupils (Class 7 and 8) and adults. The pupils exclusively analyzed porridge targeting primary school-going children while both juniors and adults analyzed porridge targeting a family set up. However, each participant analyzed only one type of porridge.

Each participant was presented with; three porridges (two newly formulated and an initial formulation for respective farmers group), clean water for rinsing the mouth before and after tasting each porridge, a scooping spoon and a scoring questionnaire where participants were asked to rank each porridge in order of preference on color, smell, taste, texture, viscosity and overall acceptability. A rank of 1-3 was used (1-Most preferred, 2-moderately preferred and 3-least preferred).

5.2.6.1 Consumer Preference Test

The participants were presented with two open-ended questions for them to state what they disliked or liked most about a particular porridge.

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5.2.7 Data Analysis

After data cleaning, data obtained from the questionnaires was analyzed using Statistical Package for Social Scientists 16.0 software (SPSS) to get summaries, means and other descriptive statistics.

5.3 RESULTS AND DISCUSION

5.3.1 Nutritional and Anti-Nutritional Composition of the Most Accepted Porridge Flour

5.3.1.1 Proximate Composition of the Most Accepted Porridge Flours

Table 5.1 shows proximate analysis findings for the most accepted porridge flours on dry weight basis. Highest fat content (%) were observed in initial formulations A (5.87) and B (4.94) which were significantly ($p<0.05$) high than the new formulations (D, E, H and I). During the development of new formulations, the aim was to reduce fat content (%) which was thus achieved. Significantly high ($p<0.05$) fibre content was observed in initial formulation B (5.74) and A (3.91) for Kapkerer and Kiptaruswo farmers' group respectively while new family formulation for kapkerer farmers' group, I (2.75) contained the least. Protein content (%) ranging 4.29 and 16.54 were observed with the highest and least being in formulation E and B respectively. Ash, CHO and energy content (%) ranging 1.76-2.36, 73.16-84.38 and 391.7-406.4 respectively were observed.

5.3.1.2 Mineral Analysis Findings for the Most Accepted Porridge Flours

Table 5.2 shows mineral content in different samples on dry weight basis. Total mineral content was consistent with the ash content (1.76-2.36%) observed (Table 5.1).

Averagely, significantly least ($p<0.05$) minerals constituents were copper (1.61mg/100g), sodium (2.68mg/100g), zinc (2.69mg/100g) and manganese (8.54mg/100g) in ascending order while potassium (872.2mg/100g) was the highest. Highest mineral content ($p>0.05$) were observed in new formulation D (1358mg/100g) and E (1464mg/100g) while formulation H (863mg/100g) and I (915mg/100g) contained the least (p>0.05mg/100g). Most of the mineral contents (mg/100g) were insignificantly different (P>0.05) across samples especially iron.

Table 5.1: Proximate composition of the most accepted porridge flours (dry weight basis)

Flour[*1]	**Proximate Composition**[*2]					
	Fats (%)	**Fibre (%)**	**Protein (%)**	**Ash (%)**	**CHO (%)**	**Energy(Kcal/ 100g)**
A	5.87±0.47[a]	3.91±0.23[b]	12.00±0.13[b]	1.82±0.11[cd]	76.40±0.72[d]	406.4±1.83[a]
B	4.94 ±0.19[b]	5.74±0.38[a]	4.29±0.39[e]	1.86±0.01[c]	83.19±0.97[b]	394.3 ±0.59[d]
D	2.82±0.08[e]	3.35 ±0.12[d]	7.19±1.11[d]	2.26±0.01[b]	84.38±1.31[a]	391.7±0.06[e]
E	4.34 ±0.07[c]	3.61 ±0.25[c]	16.54±1.45[a]	2.36±0.09[a]	73.16±1.20[e]	397.8±0.23[c]
H	3.62 ±0.45[d]	3.31 ±0.12[d]	9.34±1.68[c]	1.76±0.12[d]	81.98±0.99[c]	397.8±1.27[c]
I	3.60±0.08[d]	2.75±0.13[e]	8.59±0.25[c]	1.78±0.03[d]	83.29±0.07[b]	400±0.02[b]

[*2]Figures along the column followed by different superscript are significantly different at p=0.05. The values represent means of duplicate analysis. ± is standard deviation of two analysis.

[*1]A-Kiptarusow's Farmers group initial formulation;B-Kapkerer's Farmers group initial formulation, D-New Kiptaruswo's Farmers group children flour formulation;E - New Kapkerer's Farmers group children flour formulation;H- New Kiptaruswo's Farmers group family flour formulation, I - New Kapkerer's Farmers group family flour formulation.

The difference in respective composite flour formulations consequently affected the proximate and total mineral content of the composite flours. Adebowale *et al.*, (2017) reported lesser mineral content in cassava fortified snacks except for calcium while Khan, *et al*. (2012) reported comparable mineral content. Geographical location for growth of respective grains, their proportions in formulation of composite flour and mineral analysis methodology could have contributed to the differences. Despite the variations, the reported proximate and mineral values were within the Codex specification for cereal fortified products (Alimentarius, 1981) thus the composite flours were nutrient sufficient.

5.3.1.3 Anti-Nutrients Composition of most Accepted Porridge Flours

Table 5.3 shows anti-nutrient content in most accepted porridge flours. Phytate and tannins content ranging 0.491-2.271g/100g and 0.284-0.761g/100g respectively were observed. Significantly high ($p<0.05$) phytate content was observed in formulation A* (1.570g/100g) and B* (2.271g/100g). Least phytate and tannins content were observed in formulation B (0.491g/100g) and I (0.284g/100g) respectively. Among the new formulations, D and E contained the highest ($p>0.05$) tannins content.

During formulation of composite B* and A*, selected grains had not been optimized hence, the high phyate ($p<0.05$) and tannins ($p>0.05$) levels unlike in other formulations. Therefore, process optimization was effective in anti-nutrients reduction.

Highest tannins in new formulation D and E may have resulted from the high soybean proportion (D=10% and E= 15%) whose optimized level was observed to contain the highest tannins levels (0.47g/100g) among the selected grains.

Table 5.2: Mineral analysis (mg/100g) of most accepted porridge flours (Dry weight basis)

Composite Flour[*1]	**Type of Mineral**[*2]								**Total**
	Mn	Ca	Fe	K	Cu	Na	Mg	Zn	
A	5.55±1.86^{a}	53.31±0.51b^{c}	4.36±0.87^{a}	956.8±56.6^{bc}	0.70±0.22^{a}	4.30±0.24^{d}	109.10±2.56^{a}	3.23±0.14^{b}	**1177^{ab}**
B	4.67±0.33^{a}	48.95±2.12^{b}	3.62±0.77^{a}	967.2±73.3^{bc}	1.57±0.23^{ab}	3.58±1.09^{cd}	114.60±17.76^{a}	2.09±0.03^{a}	**1179^{ab}**
D	13.87±2.93^{c}	258.6±8.52^{e}	3.73±1.20^{a}	853.9±55.79^{abc}	1.62±0.29^{ab}	1.77±0.53^{ab}	188.8±48.43^{b}	2.54±0.32^{ab}	**1358^{b}**
E	9.46±0.18^{b}	25.13±1.57^{a}	3.74±0.34^{a}	1190.00±79.14^{c}	1.66±0.07^{ab}	3.34±0.59^{cd}	194.80±5.12^{b}	2.58±0.10^{ab}	**1464^{b}**
H	10.05±1.74^{bc}	81.41±5.90^{d}	4.21±1.18^{a}	601.8±61.46^{a}	1.73±0.56^{ab}	2.40±0.07^{bc}	120.70±8.07^{a}	3.08±0.77^{b}	**863^{a}**
I	7.63±0.24^{ab}	61.08±1.04^{c}	3.42±0.91^{a}	662.30±96.58^{ab}	2.36±0.19^{b}	0.68±0.29^{a}	143.8±19.67^{ab}	2.63±0.05^{ab}	**915^{a}**
Average	**8.54±3.41^{A}**	**88.08±81.59^{BC}**	**23.08±0.94^{AB}**	**872.2±231.2^{D}**	**1.61±0.66^{A}**	**2.68±1.33^{A}**	**145.3±39.95^{C}**	**2.69±0.47^{A}**	

[*2]Sample mineral figures along the column for lowercase and across the row for uppercase with different superscript letters are significantly different at $p<0.05$. Average figures across the row with different superscript letters are significantly different. (P=0.05). ± is standard deviation of two analysis.

[*1]A-Kiptarusow's Farmers group initial formulation; B-Kapkerer's Farmers group initial formulation; D-New Kiptaruswo's Farmers group children flour formulation; E- New Kapkerer's Farmers group children flour formulation; H- New Kiptaruswo's Farmers group family flour formulation; I-New Kapkerer's Farmers group family flour formulation.

Table 5.3: Phytate and Tannins (g/100g) content of the most acceptable porridge flours

Formulations[*1]	**Anti-nutrients**[*2]	
	Phytate	**Tannins**
A	0.620±0.161[c]	0.484±0.096[bc]
B	0.491±0.086[c]	0.578±0.105[ab]
D	0.597±0.071[c]	0.428±0.098[bc]
E	0.660±0.061[c]	0.761±0.188[a]
H	0.511±0.028[c]	0.298±0.057[c]
I	0.647±0.137[c]	0.284±0.132[c]
B*	1.570±0.046[b]	0.670±0.034[ab]
A*	2.271±0.111[a]	0.557±0.038[ab]

[*2]Figures along the column with different superscript letters are significantly different (p=0.05). ± is standard deviation of two analysis.

[*1]A-Kiptarusow's Farmers group initial formulation; B-Kapkerer's Farmers group initial formulation; D-New Kiptaruswo's Farmers group children flour formulation; E- New Kapkerer's Farmers group children flour formulation; H- New Kiptaruswo's Farmers group family flour formulation;I - New Kapkerer's Farmers group family flour formulation; B*-Non optimized Kapkerer's Farmers group initial formulation;A*-Non optimized Kiptarusow's Farmers group initial formulation

5.3.2 Sensory Analysis Findings of Different Porridges

5.3.2.1 Demographic Characteristics

Table 5.4 shows demographic characteristic of interviewed respondents. One hundred and forty nine respondents comprising both men (30.9%) and women (69.1%) were interviewed. The respondents were interviewed for either children (70.5%) or family (29.5%) porridge from Kiptaruswo (59.7%) or Kapkerer (40.3%) farmers' group. Majority of the respondents were in 11-20 yrs (77.2%) age bracket still continuing with primary education (71.1%).

Table 5.4: Demographic characteristics of the study population

Characteristics		N	Percentage (%)
Group Name	Kiptaruswo	89	59.7
	Kapkerer	60	40.3
Gender of Participants	Female	103	69.1
	Male	46	30.9
Types of porridge	Family	44	29.5
	Children	105	70.5
Age of Respondents	11-20	115	77.2
	21-30	6	4
	31-40	11	7.4
	41-50	7	4.7
	51-60	7	4.7
	>60	3	2
Level of Education	Primary School Drop outs	12	8
	Continuing primary	106	71.1
	Completed primary	3	2
	Continuing secondary	10	6.7
	Completed secondary	8	5.4
	Secondary drop out	2	1.3
	Tertiary Level	8	5.4

5.3.2.2 Children Porridge Sensory Evaluation of Developed Porridges

Figures 5.1 and 5.2 show most preference ranking (%) score of porridges against sensory attributes (color, smell, taste, texture, viscosity and acceptability) targeting school going children for Kiptaruswo and Kapkerer farmers' group respectively. Initial flour formulation for Kiptaruswo farmers' group (A) scored (%) the least in most preference scale (10.8-16.9) while formulation C (29.2-47.7) and D (35.4-52.4) scored higher. Formulation C scored slightly higher than D only on texture (47.7%) and overall acceptability (46.2%).

However, in moderate preference ranking, formulation D scored the highest in most attributes except in smell where porridge C (44.6%) scored higher than D (40.0%). Therefore, porridge D was the porridge of choice.

In Kapkerer's formulations (Fig.5.2), Initial formulation, B scored (%) lower (20-27.5) than the new formulations, E (32.5-47.5) and F (20-42.5). Formulation E scored the highest in all sensory attributes except in texture where formulation F (42.5%) scored higher thus formulation E was the most preferred porridge flour.

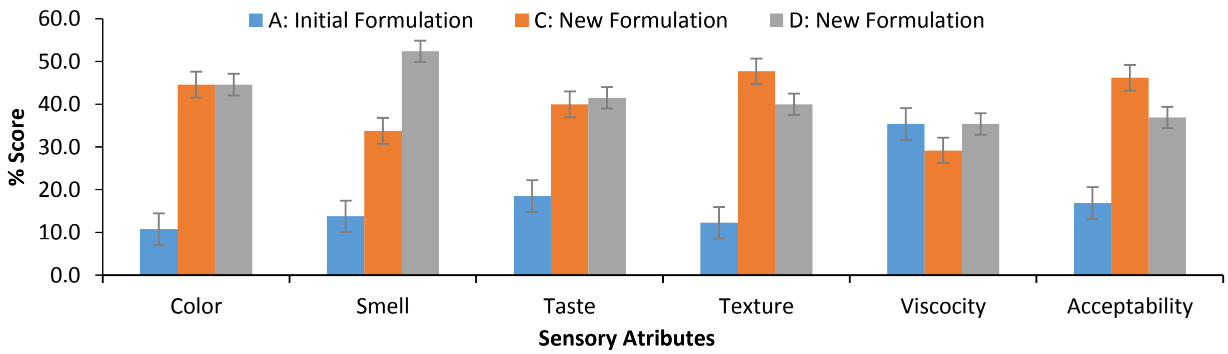

Figure 5.1: Preference ranking (%) of Kiptaruswo's children porridge against sensory attributes.

The bars indicate the standard error of means.

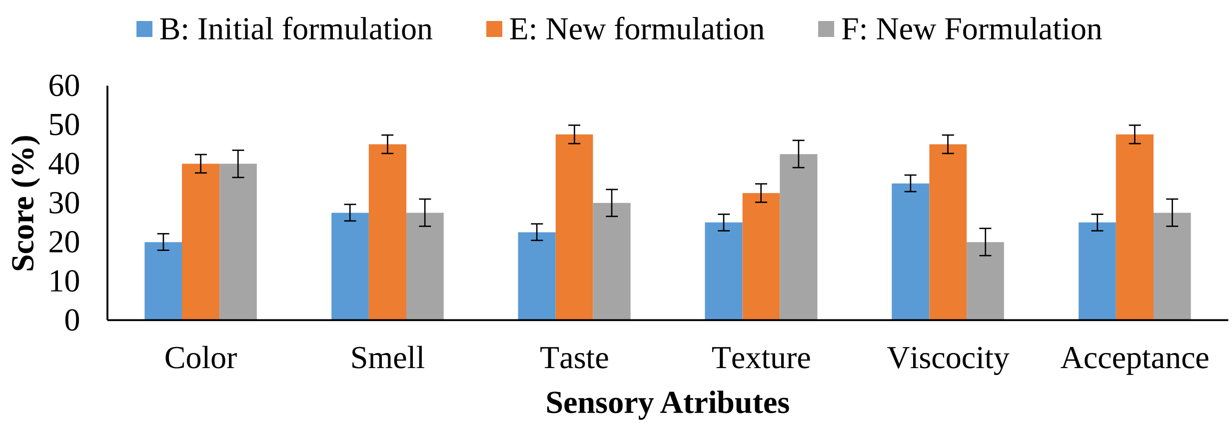

Figure 5.2: Preference (%) of different Kapkerer's children porridge.

The bars indicate the standard error of means.

5.3.2.3 Family Porridge Sensory Evaluation of Developed Formulations

Figures 5.3 and 5.4 represent most preference ranking score for Kiptaruswo and Kapkerere family porridge respectively. In the Kiptaruswo's family flour formulations (Fig 5.3) new formulation, H was the most liked (%) in most parameters (40-58.3) followed by new formulation, G (33.3-41.7) while initial formulation, A was the least liked (4.2-16.7).

In Kapkerer family flour formulations (Fig 5.4), new formulation, I was most liked (%) (20-45) in most parameters besides in color and texture where initial formulation, B scored the highest at 60 and 55 respectively. However, initial formulation (B) was least liked on viscosity (25) and acceptability (30) therefore formulation I was the most preferred.

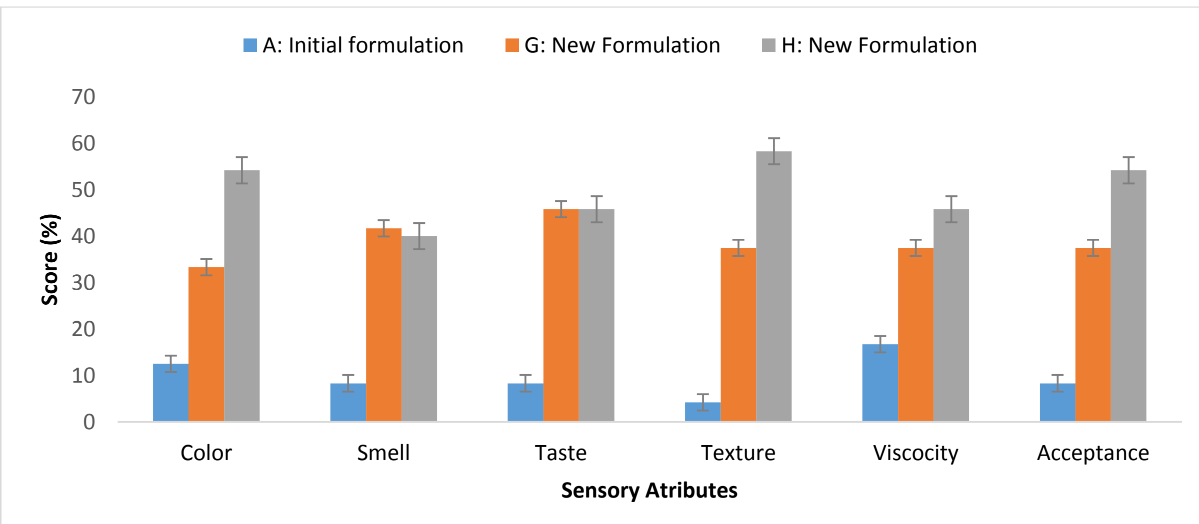

Figure 5.3: Preference ranking (%) of different Kiptaruswo's family's porridge

The bars indicate the standard error of means.

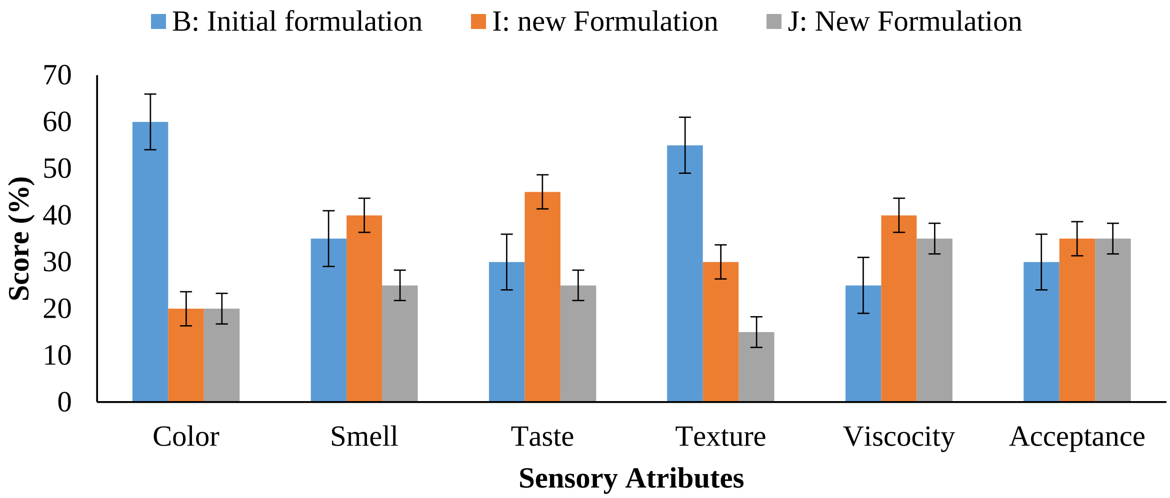

Figure 5.4: Preference ranking (%) of different Kapkerer's family's porridge. The bars indicate the standard error of means.

5.3.2.4 Consumer Liking and preference of Developed Porridges

Table 5.5 shows reasons indicated by respondent for liking/ disliking a porridge and what they valued most in porridge. Taste was the most contributing factor for respondent in liking porridge (38.9%) while color (10.7%) contributed the least. Porridge texture (32.2%) and taste (26.8%) were the most cited reasons for disliking a porridge. Porridge taste was the most considered factor in choosing the porridge ingredients especially to the primary school-going children. However, to the elderly and those with a medical condition nutrition was the most important factor.

5.3.2.5 Correlation of Sensory Attributes with Porridge Acceptability

Table 5.6 shows the correlation of the most liked attribute of porridge with the most acceptable porridge. All the sensory attributes positively correlated with porridge acceptability. Porridge viscosity was the least influencing factor while color, taste and smell were the most influential.

Smell was the most influencing factor to Kiptaruswo's respondents liking a porridge while taste and texture highly influenced the liking of Kapkerer's porridges.

Table 5.5: Consumers preference and factors considered attributed to preferences

Attributes	Attributes liked (%)	Attributes disliked (%)	Most important factors in porridge (%)	
Color	10.7	12.1	Nutrition	2.7
Smell	14.1	9.4	Color	5.4
Taste	38.9	26.8	Taste	79.2
Texture	18.8	32.2	Smell	8.7
viscosity	17.5	19.5	Texture	2.7
			Viscosity	1.3
Total	**100**	**100**		**100**

Thus they were the most distinctive characteristics among the respective porridges presented. Viscosity insignificantly ($p>0.05$) influenced the acceptability of Kapkerer porridges while in Kipatuswo porridges, it was significant ($p<0.05$). In Kiptaruswo and Kapkarer children porridges, smell (0.730) and texture (0.681) respectively were the most influencing factor while in respective farmers' group, smell and taste were the most influential factors in family porridges.

Despite porridge being a common meal or beverage among the Nandi residents, men were less receptive to the sensory analysis hence their fewer number. Sensory analysis for porridge targeting school going children was done in respective farmers's group neighboring school compound. As a result, there were many respondents analyzing for porridge targeting school going children. This explains the high respondents in school going category and respondents for the porridge targeting school going children. Different demographic characteristic were found by Font-i-Furnols *et al*., (2012) and Tortoe *et al*., (2014).

New formulations had higher proportion of finger millet, cassava and soybean than initial formulations. Finger millet taste is highly preferred in porridge hence its increased proportion in new formulations. Cassava was found to be the least fibrous among the ingredients used more so, its proportion in the new formulations was almost double the initial proportion. Its fine flour would have influenced the smoothness of the new formulations hence highest liking of new formulations on texture.

Table 5.6: Correlation of most liked porridge attributes with most acceptable porridge

Flour Type	**Sensory Attribute's**				
	Color	Smell	Taste	Texture	Viscosity
Kiptaruswo Children Porridge	0.414 (0.001*)	0.730 (0.001*)	0.560 (0.000*)	0.502 (0.000*)	0.440 (0.00*)
Kapkerer Children Porridge	0.498 (0.001*)	0.419 (0.007*)	0.571 (0.000*)	0.681 (0.000*)	0.245 (0.128)
Kiptaruswo family Porridge	0.775 (0.000*)	0.851 (0.000*)	0.702 (0.000*)	0.342 (0.102)	0.598 (0.002*)
Kapkerer family Porridge	0.031 (0.897)	0.413 (0.071)	0.508 (0.022*)	0.203 (0.391)	0.235 (0.319)

The values in bracket are the P-values. Those which were significantly different ($p<0.05$) are indicated with asterisk (*).

Legumes containing porridge are highly disliked due the imparted undesirable beany flavor (Tortoe et al., 2014). This was taken care of by roasting soybean and instead produced a desirable roasted flavor. Hence the higher liking for the new formulations on smell despite some having higher soybean proportions. Similar measures were taken by Ndagire *et al.,* (2015).Thus higher finger millet, soybean and cassava proportions in new formulations would explain the higher preference of the new formulations on taste, smell and texture in comparison to the initial formulations.

Texture was the main reason given by respondents for disliking some porridges especially the initial formulations. The rough texture was probably contributed by higher maize constituents in the initial formulations whose flour would not be as fine as cassava flour which was increased in the new formulations. More so, despite the flour having been finely ground and sieved, some hard irregularly shaped particles detectable in the mouth than the round shaped particles (Tortoe et al., 2014) may have passed through the sieve hence the undesirable texture.

Starch compose largely of amylose and amylopectin essential in development of desired porridge viscosity. Amylose is linear while amylopectin is branched at C-6 making it more stable in solutions (Capek *et al.*, 2010). During cooking, depending on moisture content and heating rate (Patel and Seetharaman, 2010), starch granules absorb water thus gelatinizing to form a gel (Onyango, *et al*., 2003) desirable in porridge cooking (Ndagire *et al*., 2015). However, since porridge was served at a lower temperature than the cooking temperature (temperature not likely to scald the respondents) viscosity of the porridges increased. Retrogradation that is time and temperature dependent which also affects viscosity, texture and sensory perception (Patel & Seetharaman, 2010) of starchy products may have happened. The increased viscosity may have been to the dislike (19.5%) or like (17.5%) of some respondents respectively. More so, Maize porridge has been found to be more viscous than millet porridge (Ndagire *et al.,* 2015). This further explains the least preference of the initial formulations against the newly formulated porridges across the target groups. Similar functional characteristic studies on porridge have been done (Ndagire *et al.* 2015; Patel and Seetharaman, 2010; Pelembe, *et al*., 2002; Tortoe et al. 2014).

All the sensory attributes positively correlated with porridge acceptability though at different strengths. Taste and texture were the most influential largely contributed by high finger millet and cassava proportion in the new formulations. This further explains the higher acceptability the new formulations against the initial formulations. Comparable findings were reported by Kikafunda, *et al*., (2006) however Tortoe *et al.* (2014) found color as the strongest correlating factor in meat.

CHAPTER SIX: QUALITY CHANGES AND SHELF STABILITY DURING STORAGE OF LEGUME BASED COMPOSITE PORRIDGE FLOURS

ABSTRACT

Food and nutrition insecurity, poverty and hunger is still prevalent in developing world especially in sub-Saharan Africa. This has necessitated increased studies on new nutrient dense product development. However, accurate quality and shelf life determination of new products is crucial but challenging to farmers groups and small scale flour processors. The current study aimed at identifying the optimal storage period of developed composite flours using different packaging materials for better quality and safety. Lablab, soybean, groundnut, finger millet, sorghum, maize, amaranth seed, pumpkin seed, wheat, buckwheat, arrowroot and cassava were used in formulation of ten different composite porridge flours. Composite flours samples were packaged in kraft paper, gunny bag and plastic container then incubated at 55^{0}C for 5 days for Accelerated Shelf Life Test (ASLT). Moisture content, color changes, acid value, yeast and molds were analyzed throughout the shelf life study. Highest moisture loss (67.04%) was found in kraft paper and least in plastic container (17.31%). The flours in all packaging materials insignificantly ($p>0.05$) lightened (L*) while losing their redness (a*) until the fifth day when color changes were significant ($p<0.05$). There was no significant ($p>0.05$) effect of packaging material on color chnages. New formulated composite flours had lower acid values D (3.77 mgKOH/g), E (3.67mgKOH/g), H (3.53 MgKOH/g), and I (3.60MgKOH/g) than their control A (7.04MgKOH/g) and B(4.29MgKOH/g). Highest acid values were observed on the second day (7.557mg KOH/g) before a decline in the consecutive days. Yeast and molds counts range (3.12-5.49 log cfu/g) observed on the initial day from different formulations increased optimally on the third day (5.59 log cfu/g) before declining inn the consecutive days. Quality and safety

changes were observed to decline fastest in kraft paper and least in plastic container. Therefore, new formulated flours would keep longer (>5months) than the initial formulations and plastic containers were the best packaging material while kraft paper was the least effective.

6.1 INTRODUCTION

High protein energy malnutrition (PEM) in developing world (Osman, 2007; Rocha-Guzman *et al.*, 2007) has pushed the need for new nutrient dense product development *(*Arab *et al*., 2010; Bojnanská *et al*., 2012; Hefnawy *et al*., 2012; Kunyanga *et al*., 2012; *Pelembe et al.*, 2002). However, accurate shelf life determination of new product is both challenging and crucial to consumers, manufacturers and government agencies (Kilcast and Subremaniam, 2000; Manzocco *et al*., 2012; Peleg and Normand, 2015; Shearer and Shearer , 2010). This has created great interest in understanding the kinetics of food degradation, how they can be monitored, predicted and stopped (Peleg and Normand, 2015).

Food products contain biological raw materials which inherently spoil over time. Although impossible to completely stop spoilage; food formulations, storage, packaging, storage and handling are some of the manufacturing measures taken to slow their spoilage (Peleg and Normand 2015; Steele, 2004). Spoilage can either be serious (causing death or illness to consumers) or less serious (change of color, texture, aroma and flavor to unacceptable level) (Steele, 2004; Rasane *et al.*, 2015). Physical, chemical and microbial changes are forms of food spoilage that are not exceptional to composite flours (Steele, 2004).

Pumpkin seed, soybean and groundnut are known to have considerable amount of fats whose stability threatens products quality and safety (Andarwulan *et al.*, 2014; Shearer and Shearer, 2010). Autoxidation are mechanism for fat deterioration depending on the fatty acids composition, moisture content, storage temperature, metals (iron and copper) and anti-oxidant reaction (Gordon, 2004) producing peroxides, radicals, alcohols, carboxylic acid, aldehydes and ketones (Broadbent and Pike, 2003; Gordon, 2004; Shahidi, 2008). Hydrolytic rancidity caused by chemical or lipolytic enzymes also results into fats degradation (Gordon, 2004; Steele, 2004). This resultantly cause economic loss and product rejection by consumers (Frankel, 2007; Gharby *et al.,* 2012; Matthäus *et al.,* 2010; Velasco and Dobarganes, 2002).

Bacteria, viruses, yeast and molds cause microbial spoilage in food products (Ray and Bhunia, 2013). However, their growth can be slowed down by adjusting storage temperature, reducing initial microbial load, reducing water activity and pH, use of preservatives and proper packaging (Steele, 2004).

Accelerated shelf life test (ASLT) is preferred to real time stability test for products with long shelf life since it's faster (Anderson 1991; Magari 2003). Temperature is known to be the best accelerating factor (Peleg and Normand, 2015; Ragnarsson and Labuza, 1977) in ASLT for products with long shelf life *(*Kilcast and Subremaniam, 2000; Magari *et al*., 2002). However, the study period should allow substantial degradation of the quality attributes giving enough data for extrapolation to real storage condition (Hough *et al*., 2006; Mizrahi, 2004; Taoukis *et al*., 1997; Tydeman and Kirkwood, 1984) . More so, acceptable limit should be known (Manzocco *et al*., 2010). ASLT is applicable to any kinetic model responsible to food spoilage whether chemical, physical or microbial (Mizrahi, 2004). However, care should be taken to avoid temperature that promotes new reactions or suppressing the old ones (Peleg and Normand, 2015). Peroxide value, sensory evaluation, anisidine value, thiobarbituric acid analysis, conjugated diens, are some of the indicators of shelf life (Kilcast and Subremaniam, 2000). Problem being solved by this has not been contextualized thus the objective of the study was to determine the quality changes and shelf life stability of newly developed composite flours using ASLT in different packaging material.

6.2 MATERIALS AND METHODS

6.2.1 Sample Collection

Sample ingredients collected for formulation and analysis included; lablab (*Lablab purpureus*), soybean (*Glycine max)*, groundnut (*Arachis hypogaea)*, finger millet (*Eleusine coracana)*, sorghum (*Sorghum bicolor*), maize (Zea mays), wheat (*Triticum aestivum)*, buckwheat (*Fagopyrum esculemtum)*, amaranth seed (*Amaranthus*), pumpkin seed (*Cucurbita spp)*, arrowroot (*Marantha arundinaceae*) and cassava (*Manihot esculenta*). They were obtained from two farmers groups producing legume based porridge flour to economically empower their members and to mitigate malnutrition in children and vulnerable groups in Nandi County, Western Kenya. The farmer groups obtain the ingredients by purchasing from neighboring Serem market Centre or from their fellow members and store them collectively in sacks. Respective ingredients stored in sacks were mixed before sampling 3kg of each, packaged separately and transported to food analysis laboratory at University of Nairobi for analysis.

6.2.2 Sample Preparation

Cleaning: All samples were sorted to remove spoilt seeds and graded for quality before wet cleaning and rinsing with tap water at ambient temperature.

Phytate and tannin reduction: This was selectively done to soybean, groundnut, finger millet and lablab. Soybean, groundnut and finger millet were soaked (at room temperature 22-25^{0}C) for 6 hours at sample to water ratio of 1:2 while lablab was soaked at 1:3 for 24 hours and boiled for 60 min. Dried groundnut and soybean were roasted for 10 min at 174 ± 2 ^{0}C in an air oven (Memmert, Germany). This was as per the research findings (unpublished results)

Drying and roasting: Wet samples were oven dried at 64 ± 2^{0}C (Memmert, Germany) before further analysis.

6.2.3 Composite Flour Formulation

The most accepted porridge flour and their control (unpublished results) targeting primary school going children and a family set up were developed for each farmers' group. The new formulations were developed using Nutrisurvey linear programming software. New formulation was based on Recommended Dietary Allowance (RDA) of an expectant mother (>4months expectant) by World Health Organization (WHO). Formulations targeted achievement of 100% of all nutrients except for fats that was thought to cause flour spoilage by oxidation

Ingredients were mixed, and ground using Black & Decker grinder and sieved through 600 μm for uniformity.

6.2.4 Accelerated Shelf Life Test Design

6.2.4.1 Accelerated Aging Time Determination

Shelf life calculation was based on Q_{10} calculation which is temperature quotient for a 10 ^{0}C temperature difference. Q10 of 3 was used since the flours were cereal based with low fats and their oxidation was not enzyme dependent. These calculations were based on Sewald and DeVries, (2003).

$$Q10 = \frac{\text{shelf life at given temperature } (t\ ^0C)}{\text{Shelf life at accelerated temperature } (t\ ^0C + 10\ ^0C)}$$

Accelerated aging time was determined by;

Accelerated aging time = Desired real time/ Accelerated aging rate

Where; Accelerated aging rate= Q10 (Te - Ta)/10) where; Te-elevated temperature and Ta-Ambient temperature

On average, flour has a shelf life of 180 days thus accelerated aging time at 55^{0}C is ≈5days hence the experiment was set for 5 days.

6.2.4.2 Sample Packaging

Packaging of the composite flour for the shelf lie study were packaged in kraft bag, gunny bag and plastic container. Each type of package material had 6 samples of 200 g each to represent each sampling day. The samples were stored in an incubator at 55 ^{0} C. The final sample was retrieved on the 5th day. The study design is as summarized in Figure 6.1.

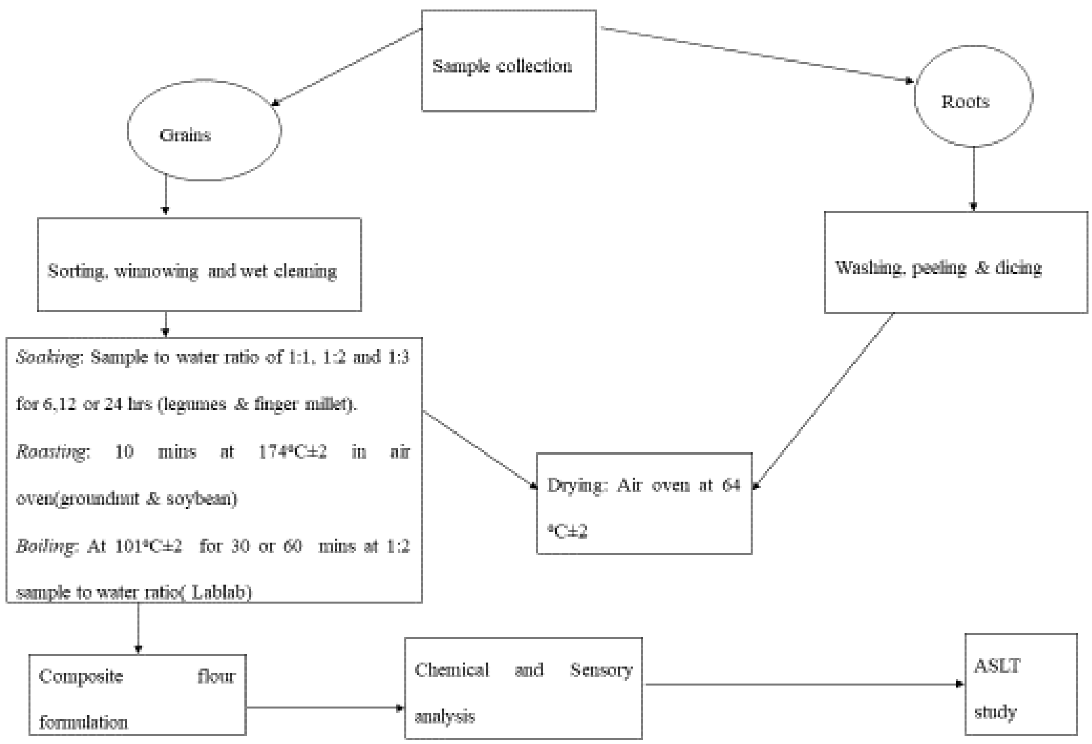

Figure 6.1: Schematic representation of Shelf Life Study

6.2.4.3 Safety and Quality Degradation Analysis

Each packaged formulation was evaluated for changes in moisture content, yeast and moulds, acid value and color.

Moisture content: Moisture content changes were determined using AOAC Method 925.10 (1990). Five gram of sample was weighed in a crucible and put in an air oven at 105° C for four hours until constant weight was achieved. The moisture content was calculated as a percentage of sample weight changes.

Acid Value: Acid value was determined by titration method, AOAC 965.33 (AOAC, 2012). Three grams of sample was weighed in a volumetric flask. Forty milliliter mixture of benzene and alcohol (1:3) was added and titrated with alcoholic KOH (0.1N) with phenolphthalein as indicator until pink color, stable for thirty seconds developed. The samples were analyzed on acid values against the maximum allowable acid value of 50mgKOH in flour (EAC, 2012) to determine the actual shelf life of flours.

Yeast and molds: Yeast and molds were analyzed according to Horizontal method for the enumeration of yeasts and molds, on potato dextrose agar. ISO 21527-1: 2008.

Color changes: Color changes were analyzed using a calorimeter (Wilford Industrial Estate, Ruddington Lane, Nottingham). Color images were taken at 3 points of each sample. Mean values were used to determine color coordinates: L∗ (lightness/darkness) and a∗ (redness /greenness)

Daily temperature and relative humidity: This was done using humidity/ Temperature data logger (RHT10 HW_SW-en-GB_V5.6.3 9/16, United States) placed inside the incubator together with the samples through-out the study. The data logger was programmed to record parameters every three hours.

6.2.5 Statistical Analysis

All analysis were carried out in duplicate and results tabulated as means plus or minus standard deviations (SD). The means were subjected to a one way analysis of variance (ANOVA) using

Gentstat 15th edition. The means were separated by Fisher's protected LSD multiple range test and difference was considered significant at $p<0.05$.

6.3 RESULTS AND DISCUSSION

6.3.1 Moisture Content, Temperature and Relative Humidity Trend over the Shelf Life Study

Figures 6.2 and 6.3 shows moisture content (%) changes in different packaging materials and temperature (^{0} C) and relative humidity (%) trend along incubation days respectively. All packaging materials allowed loss of moisture content along the incubation days. Highest moisture loss (%) was in kraft paper (67.04), gunny bags 48.15) and plastic containers (17.31) in descending order relative to their porosity. Highest moisture loss (%) was found on the first day at 56.75, 20.00 and 5.37 in kraft paper, gunny bag and plastic container respectively with consecutive days loosing lesser. Declined moisture content in flours would limit yeast and molds growth (Rodríguez, *et al.,* 2000) and increase on shelf stability of the flour (Ahmed, 2015) although over drying would impact on chemical changes essential to consumer acceptability of the flours (Jutkus, *et al.,* 2015; Sherwin and Labuza, 2003).

The data logger detected an average temperature and relative humidity (fig 6.3) of 50.3^{0}C and 17.58%, respectively. Highest relative humidity (19.8%) was observed on the initial day. This was probably from air moisture in the incubator and moisture loss from the incubated samples but declined along the incubation days from the drying effect of the incubating temperature. Declined relative humidity in the incubator consequently resulted to moisture loss from the samples. Similar moisture loss in storage was found by Rasane *et al*., (2015a). However, Kunyanga *et al*., (2012) found insignificant ($p>0.05$) moisture increase and decrease in kraft paper and gunny bag respectively at 35^{0}C of storage.

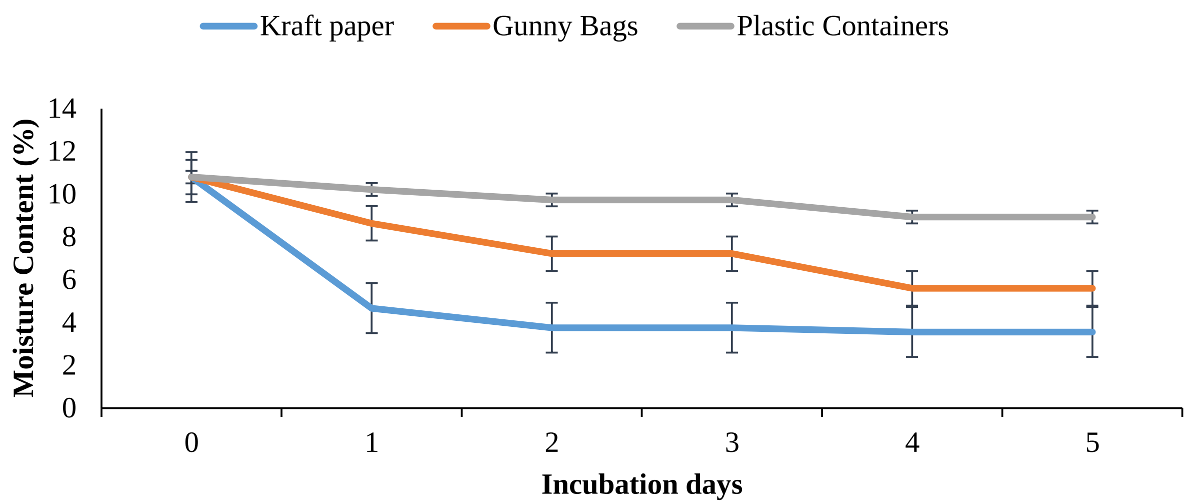

Figure 6.2: Moisture content (%) trend in different packaging material along the incubation days.

***The bars represent the standard error of means.**

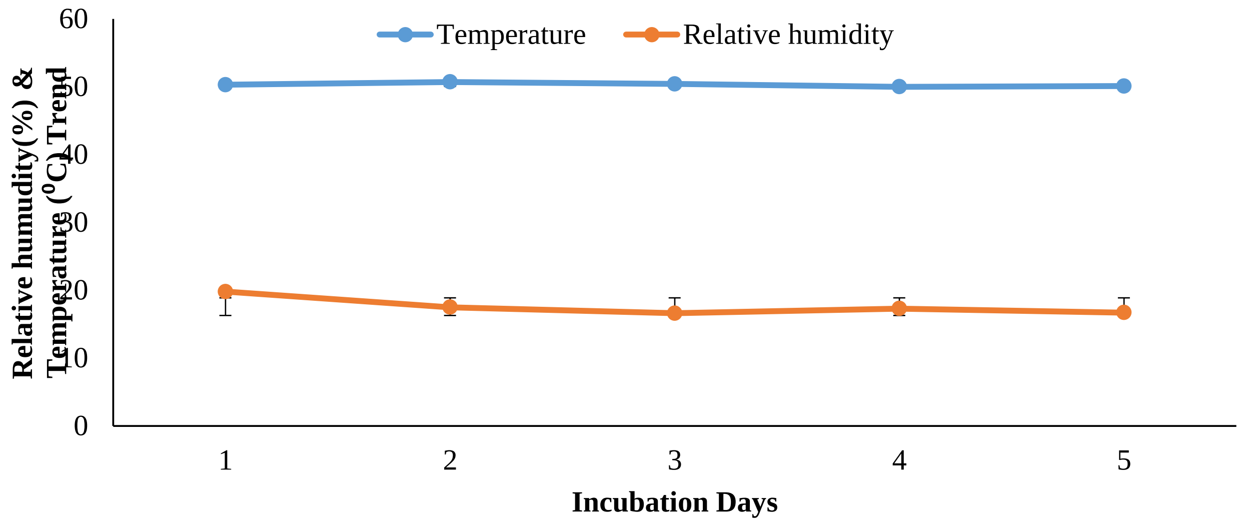

Figure 6.3: Temperature (^{0} C) and relative humidity (%) trend in the incubator over the incubation days.

***The bars indicate the standard error of means.**

6.3.2 Effect of Packaging and Storage on Color

Figures 6.4 and 6.5 show flour color changes in L*(lightness/darkness) and a* (redness/greenness) respectively in their respective package materials over the incubation days. The flour samples in the three packages continually lightened (fig 6.4) while losing their redness (fig 6.5) insignificantly ($p>0.05$) until the fifth day where the color changes were significant ($p<0.05$). L* value increased from 78.3 to 80.22, 80.02 and 80.32 while a* values declined from 3.63 to 3.03, 3.06 and 3.05 in kraft paper, gunny bag and plastic container respectively. There was no significant ($p>0.05$) color difference between the package materials.

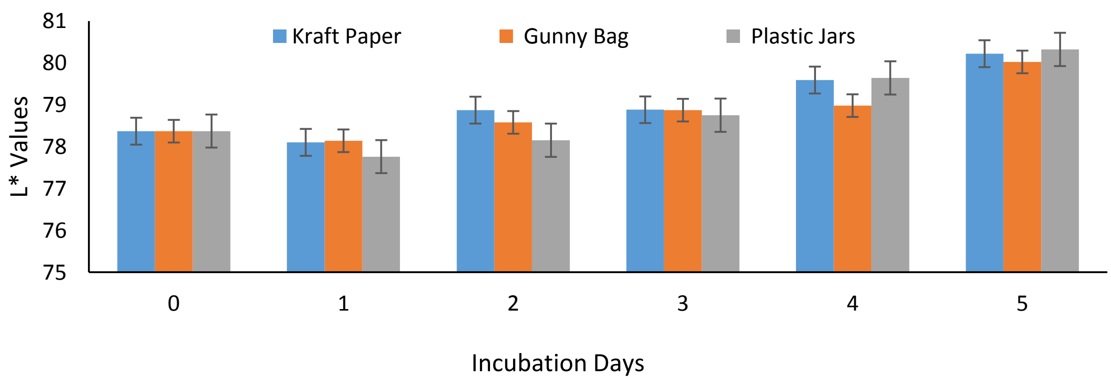

Figure 6.4: Changes in color (L*) of samples in different packing material over the incubation days.

***The bars indicate standard error of means.**

Increase in the flours lightness may have resulted to neutralization of its redness hence the lower a* vaues observed. Product color is a key determinant for product acceptability whose significant change from the normal may result to product rejection by consumers (León, Mery, Pedreschi, & León, 2006). Lipid oxidation, enzymatic and non-enzymatic reaction may have contributed to the color changes (Ukhun 1987;*Acevedo et al.*, 2008). Similar color changes during storage have been observed in honey (Gonzales *et al.*, 1999), apples (Ukhun, 1987) and meat (Petracci and Fletcher, 2018).

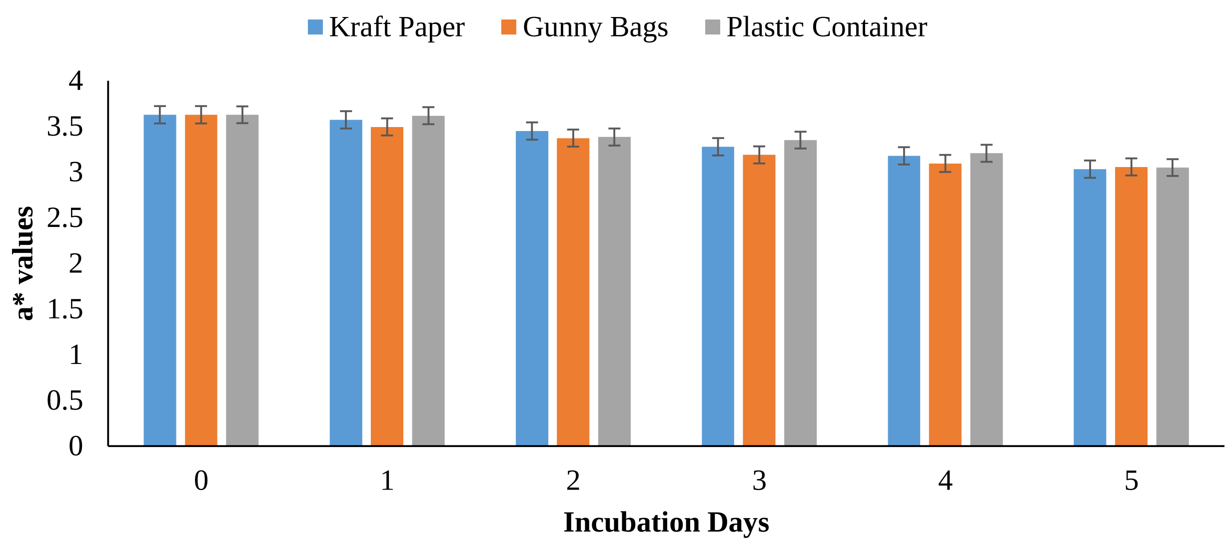

Figure 6.5: Changes in color (a*) off sample in different packaging material over the incubation days.

***The bars indicate the standard error of means.**

6.3.3 Effect of Packing and Storage on Acid Value (MgKOH/g)

Table 6.1 shows changes in acid value (Mg KOH/g) in different package materials over the incubation days of different samples (composite flour formulation not shown here). Samples reached their end point in different packages at different times. Highest acid values were found within 2-3 days in sample A and B but within 3-4 days in other formulations (D, E, H, and I). Day 1 had the least acid value though insignificantly different ($p>0.05$) from day 5. Roasting has been shown to increase degree of fats unsaturation (Valdes *et al.*, 2015). This would explains the acid levels on the initial day since groundnut and soybean were roasted.

Day 2 had the highest acid value comparable ($p>0.05$) with day 3. This means fats oxidation was highest at day 2 before declining as the days progressed but not lower than the initial day. Fats are in form of triglycerides composing of glycerol attached to a fatty acid on each of its hydroxyl group. The fatty acids can either be saturated (Lauric, myristic, palmitic, stearic and arachidic) or unsaturated (oleic, linoleic and linoleic) with the latter being important in rancidity development (Warner and Fehr, 2008). Free fatty acids are oxidized to nonacid containing by-products eg ketones and aldehydes responsible for off flavors and product rejection by consumers (Paez *et al*., 2006). This would explain the reduced acid value level from the third day.

Samples arrived at their end points in fewer days (1or 2) in plastic containers than in the Kraft paper and gunny bag (>2 days). However, acid values were averagely higher in Kraft paper than in gunny bags and plastic container. During packaging of the samples for the study, Kraft paper and gunny bag were folded hardly leaving any headspace. However, this was not possible with plastic container where a headspace containing oxygen key in fats oxidation was left (Carmen *et al*., 2009). This could have exposed the samples in plastic container to a higher oxygen concentration triggering a faster autoxidation hence the comparatively higher acid values in plastic container within the first two days (Karel, 1974; Valdes *et al*., 2015). Oxygen consumption during oxygen dependent oxidation process (Karel, 1974; Min and Wen, 1983; Koelsch, *et al*., 1991; Andersson and Lingnert, 1999) and low porosity of plastic containers unlike in kraft paper and gunny bag, could have created anaerobic condition that limited complete fats oxidations hence the lesser average acid values in the plastic containers.

Similar trend on reducing oxidative indicators have been observed in almonds (Valdes *et al.*, 2015) and whole milk (Paez *et al*., 2006). However, Mariod *et al.*, (2014) found continually increasing acid values at 70^0 C storage of rice bran oil. Higher acid values during storage were reported by Kunyanga *et al.* (2012) probably due to higher proportion of fat containing ingredients (amaranth seed and groundnut) used in composite flour formulation.

Table 6.1: Acid value (mg KOH) of differently packaged samples over the incubation days

Flour[*1]	Packaging Material	Acid Value (mg KOH/g) [*2]						
		Incubation Days						Mean
		0	1	2	3	4	5	
A	Crafts paper	7.04 ± 3.70^{ab}	7.82 ± 1.62^{ab}	14.11 ± 1.09^{d}	13.25 ± 0.27^{cd}	8.11 ± 1.19^{ab}	7.10 ± 1.58^{ab}	**9.57^{I}**
	Gunny bags	7.04 ± 3.70^{ab}	7.37 ± 1.55^{ab}	8.21 ± 2.12^{ab}	5.82 ± 1.39^{ab}	4.60 ± 0.34^{a}	4.30 ± 0.27^{a}	**6.22^{DEFG}**
	Plastic	7.04 ± 3.70^{ab}	9.29 ± 2.86^{bc}	8.22 ± 1.84^{ab}	5.35 ± 0.07^{ab}	5.33 ± 0.66^{ab}	4.25 ± 1.27^{a}	**6.58^{EFG}**
B	Crafts paper	4.29 ± 0.85^{a}	7.91 ± 2.78^{cde}	12.71 ± 0.01^{f}	7.54 ± 0.87^{bcde}	5.64 ± 1.26^{abc}	5.54 ± 0.22^{abc}	**7.27^{GH}**
	Gunny bags	4.29 ± 0.85^{a}	4.53 ± 0.29^{a}	9.81 ± 1.44^{e}	7.02 ± 0.33^{abcde}	6.96 ± 0.38^{abcde}	5.45 ± 0.53^{abc}	**6.34^{DEFG}**
	Plastic	4.29 ± 0.85^{a}	8.91 ± 3.99^{de}	6.10 ± 0.96^{abcd}	5.71 ± 1.04^{abc}	5.46 ± 0.94^{abc}	4.86 ± 0.06^{ab}	**5.89^{CDEFG}**
D	Crafts paper	3.77 ± 0.50^{a}	6.34 ± 0.52^{abc}	8.51 ± 2.52^{bcde}	8.98 ± 0.53^{cde}	11.58 ± 2.91^{e}	11.02 ± 0.77^{de}	**8.37^{H}I**
	Gunny bags	3.77 ± 0.50^{a}	7.19 ± 2.13^{abc}	7.36 ± 1.79^{abcd}	9.41 ± 2.68^{cde}	6.87 ± 0.72^{abc}	4.98 ± 0.15^{ab}	**6.60^{FG}**
	Plastic	3.77 ± 0.50^{a}	5.18 ± 2.95^{ab}	8.64 ± 1.10^{bcde}	8.19 ± 2.50^{bcde}	6.25 ± 0.67^{abc}	4.39 ± 2.51^{a}	**6.07^{CDEFG}**
E	Crafts paper	3.67 ± 0.54^{ab}	4.76 ± 0.05^{abcde}	7.00 ± 1.48^{cdef}	7.39 ± 0.62^{def}	7.28 ± 1.36^{def}	4.09 ± 1.27^{abc}	**5.70^{BCDE}F**
	Gunny bags	3.67 ± 0.54^{ab}	5.70 ± 1.46^{abcdef}	6.13 ± 0.87^{abcdef}	8.39 ± 0.25^{f}	4.30 ± 1.23^{abcd}	4.52 ± 1.43^{abcde}	**5.45^{BCDEF}**
	Plastic	3.67 ± 0.54^{ab}	6.20 ± 4.52^{bcdef}	7.66 ± 2.64^{ef}	6.06 ± 0.02^{abcdef}	3.83 ± 0.13^{ab}	2.99 ± 0.27^{a}	**5.07^{ABCDE}**
H	Crafts paper	3.53 ± 0.10^{a}	3.72 ± 0.04^{a}	4.25 ± 1.06^{a}	4.48 ± 0.01^{a}	4.97 ± 2.45^{a}	4.25 ± 0.94^{a}	**4.20^{AB}**
	Gunny bags	3.53 ± 0.10^{a}	3.64 ± 0.40^{a}	4.46 ± 0.16^{a}	4.67 ± 0.26^{a}	4.95 ± 2.24^{a}	4.21 ± 0.20^{a}	**4.24^{AB}**
	Plastic	3.53 ± 0.10^{a}	4.20 ± 0.40^{a}	4.85 ± 0.27^{a}	3.82 ± 1.18^{a}	3.74 ± 0.01^{a}	3.45 ± 0.67^{a}	**3.93^{A}**
I	Crafts paper	3.60 ± 0.08^{ab}	4.36 ± 3.03^{abc}	5.29 ± 0.04^{bcd}	5.64 ± 0.38^{bcde}	8.39 ± 0.85^{e}	8.31 ± 4.63^{de}	**5.93^{CDEFG}**
	Gunny bags	3.60 ± 0.08^{ab}	4.20 ± 0.65^{abc}	5.79 ± 0.52^{bcde}	6.16 ± 1.59^{bcde}	6.81 ± 0.41^{cde}	3.74 ± 0.53^{ab}	**5.05^{ABCD}**
	Plastic	3.60 ± 0.08^{ab}	5.44 ± 0.21^{bcde}	6.94 ± 1.24^{cde}	6.41 ± 0.78^{bcde}	3.60 ± 0.08^{ab}	2.23 ± 0.58^{a}	**4.70^{ABC}**
	Mean	**4.317^{A}**	**5.932^{B}**	**7.557^{C}**	**6.905^{C}**	**6.038^{B}**	**4.983^{A}**	

[*2] Values with different superscript under the same sample are significantly different. Mean values followed by different superscript are significantly different. P=0.05. [*1]A-Initial composite porridge flour for Kiptaruswo; B- Initial composite porridge flour for Kapkerer;D-Newly formulated kiptaruswo' children flour;E- Newly formulated kapkerer' children flour; H- Newly formulated kiptaruswo' family flour;I-Newly formulated kapkerer' family flour.

6.3.4 Effect of Packaging and Storage on Yeast and Moulds Growth (Log Cfu/g)

Table 6.2 shows changes in yeast and molds (log cfu/g) population in different packaging over the incubation period. All the samples showed varying initial growth of yeast and molds portraying different levels of contamination of each sample. Sample E was the most contaminated while sample I was the most clean. Despite having observed hygiene during ingredients preparation, there must have been a carry-over of yeast and molds from harvesting field or post harvesting processes (Muthomi and Murutu, 2003; Muthomi *et al*., 2012; Al-defiery and Merjan, 2015; Kibe, 2015).

Yeast and molds were significantly higher ($p<0.05$) on the second and third day before declining from the fourth day. Fungi kingdom have different species with varying temperature and moisture requirements for their growth (Pitt and Hocking, 2009). The high temperatures ($\approx 50^0$ C) used during the experiments and a decline in moisture content (%) of the samples across the incubation days may have hindered growth of some species hence the decline in total growth. Averagely, yeast and molds grew fastest in Kraft paper with the plastic container delaying the longest. Oxygen consumption during fats oxidation (Valdes *et al*., 2015) and fungal growth with production of carbon dioxide (Richards and Haynes, 1932) may have inhibited some species from growth hence the decline on total yeast and molds counts especially in plastic container.

Table 6.2: Changes in yeast and mold population in different composite porridge flours and packages under ASLT.

Flour[*1]	Packaging Material	Count of Yeast and Molds (log cfu /g) [*2]						
		Incubation Days						Mean
		0	1	2	3	4	5	
A	Crafts paper	3.69±0.04[b]	5.48±0.01[g]	7.15±0.01[i]	6.24±0.01[g]	5.48±0.04[g]	4.59±0.02[f]	**5.44 [def]**
	Gunny bags	3.69±0.04[b]	3.95±0.01[c]	7.21±0.01[i]	6.27±0.03[h]	4.13±0.18[d]	3.59±0.07[b]	**4.81[bc]**
	Plastic container	3.69±0.04[b]	3.69±0.10[b]	7.45±0.01[j]	4.43±0.09[e]	4.54±0.03[ef]	3.15±0.21[a]	**4.49[b]**
B	Crafts paper	3.45±0.07[a]	4.48±0.01[bcd]	7.44±0.01[g]	7.20±0.01[g]	5.50±0.07[def]	5.28±0.01[cdef]	**5.56[def]**
	Gunny bags	3.35±0.07[a]	4.12±0.01[ab]	4.58±0.06[bcd]	6.09±0.01[f]	4.53±0.11[bcd]	4.34±0.06[abc]	**4.52[b]**
	Plastic container	3.45±0.07[a]	4.33±0.01[abc]	4.82±0.02[bcde]	5.75±2.05[ef]	5.31±0.01[cdef]	4.00±0.01[ab]	**4.61[b]**
D	Crafts paper	4.49±0.01[a]	4.86±0.03[bcd]	4.98±0.06[cde]	7.00±0.02[h]	6.23±0.02[g]	4.81±0.03[abc]	**5.40[def]**
	Gunny bags	4.49±0.01[a]	5.11±0.01[cde]	5.66±0.69[f]	5.64±0.08[f]	5.27±0.01[e]	5.14±0.01[cde]	**5.22[cde]**
	Plastic container	4.49±0.01[a]	4.49±0.01[a]	4.51±0.05[ab]	4.53±0.11[ab]	4.55±0.10[ab]	5.20±0.11[de]	**4.63[b]**
E	Crafts paper	5.49±0.01[abc]	5.82±0.70[cde]	6.03±0.05[def]	6.45±0.01[f]	6.40±0.14[f]	5.14±0.01[ab]	**5.89[f]**
	Gunny bags	5.49±0.01[abc]	5.88±0.69[cde]	6.08±0.03[def]	6.41±0.01[f]	5.23±0.03[ab]	5.08±0.01[a]	**5.69[ef]**
	Plastic container	5.49±0.01[abc]	5.50±0.01[abc]	6.04±0.09[def]	6.21±0.01[ef]	5.61±0.11[bcd]	5.27±0.02[ab]	**5.68[ef]**
H	Crafts paper	4.49±0.01[bcd]	4.76±0.08[de]	4.81±0.05[de]	6.29±0.01[f]	6.59±0.08[f]	4.31±0.01[ab]	**5.21[cde]**
	Gunny bags	4.49±0.01[bcd]	4.85±0.01[de]	4.90±0.73[e]	4.72±0.06[cde]	4.35±0.04[abc]	4.09±0.12[a]	**4.57[b]**
	Plastic container	4.49±0.01[bcd]	4.65±0.04[bcde]	4.97±0.01[e]	4.97±0.01[e]	6.40±0.17[f]	4.50±0.03[bcd]	**5.00[bcd]**
I	Crafts paper	3.12±0.03[a]	3.23±0.01[ab]	3.30±0.43[ab]	3.43±0.02[b]	3.25±0.07[ab]	3.26±0.03[ab]	**3.27[a]**
	Gunny bags	3.12±0.03[a]	3.34±0.03[ab]	3.43±0.03[b]	4.29±0.01[c]	3.19±0.14[ab]	3.21±0.02[ab]	**3.43[a]**
	Plastic container	3.12±0.03[a]	3.37±0.04[ab]	7.31±0.01[e]	4.60±0.03[d]	4.57±0.22[d]	4.25±0.07[c]	**4.54[b]**
	Mean	**4.12[A]**	**4.55[A]**	**5.59[C]**	**5.59[C]**	**5.06[B]**	**4.40[A]**	

[*2]Values with different superscript under the same sample are significantly different. Mean values followed by different superscript are significantly different (P<0.05). [*1]A-Initial composite porridge flour for Kiptaruswo, B- Initial composite porridge flour for Kapkerer, D- Newly formulated kiptaruswo' children flour, E- Newly formulated kapkerer children flour, H- Newly formulated kiptaruswo family flour, I- Newly formulated kapkerer family flour.

6.3.5 Actual Shelf Life Calculation

In the present study, none of the sample got to the maximum allowable acid value limit of 50mgKOH (East Africa Standards, 2012) thus actual shelf life was longer than five mongths.

Lipids are triglycerides composing of a glycerol moiety esterified with three fatty acids molecules which can either be saturated or non-saturated. Saturated fatty acids are stable while the mono or the poly unsaturated fatty acids are unstable to oxidation (Theodore and Dugan, 1971; Galano *et al*.,2015;). Oxidative rancidity which is a spontaneous reaction of unsaturated fatty acids in company of atmospheric oxygen (Coultate, 2009) is key determinant of spoilage in fat containing foods (Ahmed *et al*., 2016). Initiation, propagation and termination steps are followed in fats oxidation (Barriuso *et al*, 2013; Ahmed *et al*.,, 2016). Initiation step is catalyzed by high temperature, light, metal ions or presence of a double bond (Barriuso *et al*, 2013) where a hydrogen atom from a double bond is extracted and a free radicals is formed (Brown, 2011, Lee *et al*., 2004). Oxygen atom reacts with free radicals to form peroxy radicals which reacts with hydrogen atom from another unsaturated double bond to form hydroperoxide (Julia et al., 2015). Hydroperoxides are broken further to carbonyl compounds, aldehydes, ketones and short fatty acids in the propagation steps. This can be accelerated by higher temperature (Shahidi and Wiley, 2005) hence the use of temperature in ASLT. Short fatty acids formed are further broken down to aldehydes (Theodore and Dugan, 1971) this would have contributed to the reducing acid values observed.

In the termination step, free radicals reacts with each other forming a non-radical compound thus terminating oxidation cycle (Gutowski and Kowalczyk, 2013). Propagation step has been shown to be oxygen and fat content dependent (Andersson and Lingnert 1999; Carmen *et al*., 2009). This would explain the declined fatty acids value over the incubation days as a result of declined oxygen content especially in the plastic container which are less porous to oxygen.

Fatty acids values may also not have reached the maximum allowable limit (50mgKOH) (East Africa Standards, 2012)due to the lower fats contents in the flour in comparison to studies done by (Kunyanga et al., 2012) whose products had higher fat content (18%) in comparison to fat content (3-≈6%) of composite flour under study (Section 5.3.1.1).

CHAPTER SEVEN: GENERAL CONCLUSION AND RECOMMENDATION

7.1 GENERAL CONCLUSIONS

A diversity of different food ingredients was utilized by farmers which included; legumes, cereals, pseudo-cereals and roots. Farmers seemed informed on the nutritional richness differences among them with more preference to legumes while roots were the least preferred. Price, organoleptic characteristics and cultural values highly influenced proportioning of each ingredient in composite flour formulations. As much as farmers were aware of the importance and means of proper processing practices they were not keen in following them. Seeking to understand farmers' reasoning behind their choice of ingredients in composite flour formulation was useful in guiding on development of the improved formulations.

Ingredients utilized in composite porridge flour formulations were observed to have varying levels of proximate and mineral content. Selected grains were also found to have varying phytate and tannins content known to reduce nutritional values of respective product. However, proper process optimization by soaking, boiling and roasting were found to be effective in their reduction.

All the newly formulated products were more preferred to initial porridge flour formulations. Taste and texture were the most essential factors in porridge while smell and color contributed to porridge preference the least. Optimization steps identified were found to be effective in tannins and phytate reduction in composite flour. More so, all the formulations were found to be adequate in meeting nutritional requirement of the targeted demographics. Thus, informed proportioning of each ingredient in product formulation in addition to optimized processing steps would be adequate in nutrient dense product development.

Different porridge composite flours were found to spoil at varying rate in different packaging materials. Except on color changes, packaging material were found to significantly ($p<0.05$) affect; rate of moisture loss, fats breakdown and yeast and molds growth. Plastic container limited moisture loss, high fatty acids breakdown and yeast and molds growth. This makes plastic container better packaging material for the flour in comparison to kraft paper and gunny bags. Newly formulated products spoilt at a lower rate than the initial formulations thus the new formulations' shelf stability had been improved. Thus packaging new formulated flour in plastic container would significantly improve on shelf life of the initial formulations.

7.2 GENERAL RECOMMENDATIONS

Farmers processing protocols were wanting thus, consistent training and follow up with them should be done to ensure safe and quality porridge flour is produced. More so, farmers should be empowered with dependable drying systems of ingredients especially during the rainy season, provided with an automatic moisture detection machine and proper storage containers that are resistant to pest, durst or environmental moisture.

The new composite porridge flour formulated, were costlier than the initial formulations which can negatively affected farmers' groups customer loyalty. This can however be averted by; encouraging individual farmers on producing the ingredients in bulk and selling to the group at a cheaper price than the market value, educating their customers on the nutritional, safety and quality value added to the new product or purchasing the ingredient in bulk during the peak season at a cheaper price. More so, Commercialization and marketing of new developed composite flour should be done using effective business models.

Accelerated shelf life study used is bound to errors thus a real shelf life study of the same should be done. The research had rich informative findings which if adopted and implemented will be beneficial to processing farmers and consumers at large. However, this can only be successful if adoption of the research findings is consistent therefore follow up with the processing farmers group is paramount.

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APPENDICES

APPENDIX I: FOCUSED GROUP DISCUSSION GUIDE

1. Which ingredients do you use in your composite flour? Kindly list them
2. Which ingredients do you have to buy out of the listed above?
3. Do you understand the nutritional value of each ingredients? If yes, kindly explain
4. How would you list the flour ingredients in order of preference in relation to; Taste, color, smell, texture, cultural attachments, cost and good health impact?
5. Which ingredients do you think serve the same purpose/ can compensate each other?
6. Which ingredients can your consumers not be willing to trade off? Kindly give the reason.
7. Which is the most preferred taste, color, flavor and texture of porridge?
8. Of what use do your consumers put the composite flour?
9. Do you think the composite flour is appropriate for children? Yes/No. Give reasons.
10. Which steps do you follow in your production process?
    a. What is the importance of each step?
    b. Do you think there is need for improvement? Why?
    c. Which modifications/ additional steps do you think could be added?
    d. How do you package, where do you keep and for how long?
11. How many flour would you wish to process? Which are the target groups?

APPENDIX II: QUESTIONS TO THE HEALTH OFFICER(S)

Name of Health facility…………………………………………….

Location of health facility…………………………………………

1) Which are the most common nutrition related illnesses?
2) Who are the most affected?
3) Which type of food do you recommend them to eat?
4) What is the prevalence of PEM?

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APPENDIX III: INFORMED CONSENT FORM

Study Name: Process Analysis, Nutritional Quality and Consumer Acceptability of Composite Flours Developed from Legume-Based Ingredients Grown in Nandi County

Investigator: Peninah W Gitau

Reg No: A56/82018/2015

Msc. Food safety and quality

University of Nairobi

Purpose of the research

The purpose of the study is to identify the most acceptable composite flour porridge that will also meet the nutritional requirements of the target groups.

Your part in the research

You are requested to co-operate in this study by answering the questions in the questionnaire and providing any other information as pertains to the study.

Possible benefits

The research outcomes will be beneficial to the farmers groups currently processing the porridge flour on improving safety and nutritional quality of the current flour while considering nutritional, cultural values and sensory preference of their target consumers.

Possible Risks

There are no foreseen risks associated with the study.

Compensation

Your participation is voluntary and therefore, you will not receive any form of compensation.

Volunteer Agreement

I have read the consent form describing benefits, risks and procedures. I voluntarily agree to participate.

Date……./……./2018 Name/signature……………………

For official use only

I certify that the nature, purpose, the potential benefits and possible risks associated with participating in this study have been explained to the above individual

D**ate……………………………………… Signature……………………….**

APPENDIX IV: PORRIDGE FLOUR ACCEPTANCE SURVEY QUESTIONS

Sex of respondent [F] [M] Age ………………….

Name of group ………………………………………………………………………….

Level of Education……………………………………………………………………….

You are presented with three differently formulated porridges. Staring with any order, using a spoon provided, take a scoop, hold it in your mouth for 10 seconds and rate it on; taste, color, smell, texture and overall acceptability. Proceed through the other samples in similar manner, rinsing your moth in between each sample.

Rank each porridge as 1, 2 or 3 where:

1= Most preferred; 2= Moderately preferred; 3= Least preferred

Attributes	**Coded Porridges**
Color	
Smell	
Taste	
Texture	
Overall Acceptability	

Consumer preference questions

1) What did you like about the flour you picked as your most favorite?

2) Why did you not like about the one you picked as your least favorite?

3) What is your most important factor when buying porridge flour? nutrition, color, taste, smell, how filling it is, other?”