EFFECT OF SOY FORTIFICATION ON PROXIMATE, FUNCTIONAL AND SENSORY CHARACTERISTICS OF CASSAVA BASED FLOURS AND PRODUCTS

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A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS OF THE DEGREE OF MASTER OF SCIENCE IN COMMUNITY NUTRITION IN THE DEPARTMENT OF FAMILY AND CONSUMER SCIENCES OF THE SCHOOL OF AGRICULTURE AND BIOTECHNOLOGY, UNIVERSITY OF ELDORET, KENYA

2017

DECLARATION

Declaration by candidate

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DEDICATION

This thesis is dedicated to:

My loving husband, for foreseeing my vision and continued support both financially and emotionally throughout my studies, you made it happen by God’s grace. May the almighty God meet the desires of your hearts. To My lovely children, Caleb, Othniel and Dorcus for understanding even when it was difficult, but allowed me to be away. Lastly my parents, the late Mr. Gabriel Otunga Mukanda and Mrs. Dina Otunga, who laid a foundation for my studies.

ABSTRACT

Diets in most households in developing countries are based on starchy staples which do not provide sufficient proteins for children below age five, predisposing them to Protein Energy Malnutrition. Cassava is one such staple consumed in Western Kenya in form of ugali and porridge either singly or mixed with millet, maize or sorghum. Fortification of cassava with a legume is a sustainable approach to improve the protein quality, and content and nutrient density of staple food products. The aim of this study was to investigate the effect of soy fortification on the proximate, functional and sensory characteristics of cassava cereal composite flours and products. To establish the nutrient composition, proximate analyses included the determination of moisture, crude protein, crude fat, ash and carbohydrates using the AOAC Internationally approved methods. For the functional tests, bulk density, water and oil absorption capacities and viscosity were determined. Sensory evaluation of porridge was conducted using a trained descriptive panel consisting of 10 members, who generated descriptors, while a consumer panel was used to test acceptability of the cassava cereal soy fortified porridges using a 9-point hedonic scale. The proximate results showed a significant increase in the protein, mineral and lipids content of the cassava and its composites by 89%, 71% and 69%, respectively at 30% fortification and at 50% fortification, 95% 89% and 79%, respectively. All millet based ugali variations including the plain, composited and fortified had higher proximate values for ash, fat and protein compared to maize and sorghum variations. The protein content of porridge was higher than ugali by 55%. Soy fortified flours had better functional characteristics. Bulk densities ranged from 1.4 g/cm^3 for millet flour to 1.69 g/ cm^3 for cassava: millet: soy 50%, water absorption capacity from 84.7 ml/100 g for cassava maize to 141.7 ml/ 100 g for cassava millet soy 50%, viscosity from 2.68 for maize meal porridge to 4.83 for cassava soy 50% and fat absorption capacity from 72.67 ml/ 100 g for cassava maize to 95.67 ml/100 g for cassava millet soy 50%. The sensory panelists were able to generate 23 sensory descriptors which they used to evaluate eight porridge variations. The first two Principal Component Analyses (PCA1 and 2) explained 64% of the variation in sensory attributes based on fortification at 41.55% for PCA1 and colour intensity at 22.26% for PCA 2. PCA3 explained the source of variation by 14.2% based on texture. Consumer panelists preferred the soy fortified porridges which were darker in colour especially cassava millet soy 30%, 50% and cassava soy 50%. In conclusion, porridges and ugali fortified at 30% were found to provide 50% of the daily protein requirements per 100 g for children aged 1-3 years. The soy fortified porridges scored better per sensory descriptors and were found acceptable by the consumer panelists therefore can be used for supplementary feeding in schools to alleviate PEM as well as household consumption in Western Kenya or any other population.

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ACRONYMS

AOAC -Association of Official Analytical Chemists'

FAO -Food and Agriculture Organization

GAM - Global Acute Malnutrition

IFAD -International Fund for Agricultural Development

IITA -International Institute of Tropical Agriculture

PEM -Protein Energy Malnutrition

UNICEF -United Nations Child Fund

WHO -World health Organization

ACKNOWLEDGEMENT

First and foremost I give thanks to God Almighty, the maker and designer of my being, who gives me breath and chance to embrace another dawn. I would also like to thank my supervisors, Dr. Charlotte A Serrem and Dr. Beatrice Imo for their tireless advice in working out this document. Everything you said put more life in this work. I am grateful to you for your timely advice, constructive criticism and addition which made this document what it is today, thank you and God bless you. I would also like to appreciate VLIR-OS for partially funding this research. The Family and Consumer Sciences head of department, Dr. Gertrude Were is appreciated for guidance leadership and direction which has kept our learning and the department running. The lecturers for imparting knowledge and mentorship that has made me what I am today. Technicians for imparting practical skills and the support you have always offered. Mr. Edwin Kirwa, the technician in the Chemistry laboratory for his time and guidance during my research even on weekends and Easter holidays, Sir you made it happen. My classmates, the 2012 class for adding value to my work critically, encouragement and the support you offered during my research especially Catherine Mutinda. Not forgetting the descriptive sensory panelists Esther, Lillian, Prisca, Gloria, Victoria, Samuel, Smith Brian, Paul and George, thanks a lot for accepting the call and staying through. Additionally I appreciate my dear sisters; Kate, Obinda, Edna and Dorcus for taking care of my children and encouragement to push on while I was away studying. Last but not least my

husband, Jackson Sikuku for all the financial and emotional support in working out this degree and the rest of the academics, God bless you all.

CHAPTER ONE

INTRODUCTION

1.1. Background of the study

Malnutrition remains an important public health issue particularly for children under 5 years whose morbidity and mortality rates are high (Unicef, 2009). Globally, 667 million children are malnourished (International Food Policy Research institute [IFPR1, 2016]). Of importance, is that most households in developing countries depend on staple diets providing plenty of carbohydrates, but which are unable to meet their minimum daily protein requirements (FAO/WFP/IFAD, 2012). The quality of weaning foods for children determines their vulnerability to Protein Energy Malnutrition (PEM) (Anuonye, 2011). For instance, traditional weaning foods in African households are derived from cereal staples (Ugwu, 2009) with little or no addition of protein rich foods (Bwibo & Neumann, 2002). This predisposes such children to PEM making it necessary to develop nutrient dense foods that provide better quality diets.

Studies have shown that fortifying staples with legumes improves the quality of diets (Mutambuka, 2013; Opeifa *et al*, 2014). Legumes like soy bean (*glycine max*), cow peas (*Vigna Unguiculata*) and oil seeds such as peanut *(Arachis hypogea*) have been used in many such studies. Martin, Kulwa & Laswai (2010) recommended that locally available foods should be combined to create new nutrient patterns that are sustainable thus increasing the nutrient quality of diets.

Cassava is a drought resistant staple that is important for food security (International Institute of Tropical Agriculture (IITA) 2008), unfortunately it has very low protein content, approximately 1.4 g/100 g (Olumide, 2004) and the protein is of poor quality (Akoja & Mohamed, 2009). Formulation of foods using low protein quality staples fortified with legumes was proposed by FAO/WHO (1994) as one of the most practical and sustainable approaches to improving the nutritional value of foods for children and households in developing countries. Soy bean contains high quality protein equal to animal source foods (Martin *et al*, 2010). Therefore, cassava can be fortified with soy bean to improve its protein quality and nutrient density.

In western Kenya cassava is grown and consumed as one of the staples in many forms by households including children (Were, 2010). Stephenson *et al* (2010) reported that 53% of all children 2-5 years in cassava growing and consuming areas of Kenya did not get adequate proteins in their diets. These children were specifically from Busia and Kuria districts. The growth of soy bean has been promoted extensively among small smallholder farmers as a cheap source of protein and a cash crop among households in this region making it the leading producer of soy bean in Kenya (Chianu *et al*, 2008).

However, its consumption is still low in households (Chianu *et al*, 2009) and children are malnourished (Kenya Demographic and health survey [KDHS, 2015]). Developing cassava products fortified with soy bean using frequently consumed dishes could enhance the utilization of soy bean as a protein and quality of diets. Onyango, Ambitsi and Oucho (2008), evaluated sensory quality and acceptability of soy products in Navakholo, western Kenya reported that fried soy bean was liked best followed by porridge but soy maize ugali was least liked. These findings demonstrate that consumption of soy bean can be increased to complement cassava based diets and other staples. Therefore the aim of this study was to determine the effect of soy fortification on the nutrient composition, functional and sensory characteristics of cassava based composite flours and products. The fortified product can then be used in Western Kenya and similar areas.

1.2. Statement of the problem

In Kenya, 35% of all the children aged 5 years and below were stunted, 7% wasted and while 16% were underweight (KDHS, 2010). A recent report shows that stunting rates nationally have dropped to 27% which is still high, wasting to 4% while underweight to 11% (KDHS, 2015). Nzuma and Ocholla (2012) in an earlier survey in high density urban households reported global stunting at 26.5%, while global underweight was 2.7 %. The KDHS (2010) in addition reported that 28.8% of all the children below five years were stunted, 2.6% were wasted and 14.8% were underweight in Western Kenya. Despite the fact that there was overall improvement in nutritional status of children under five years for according to current statistics, the situation worsened for western Kenya. The KNBS (2015) reported that the rates increased to 33.4% stunting, 2.9% wasting and 10.5% underweight for Busia County of western Kenya. Surprisingly, these rates are higher than the national rates indicating a serious nutrition problem in the region that requires urgent intervention.

In a comparative study on the adequacy of protein intake in the diets of children 2-5 years from cassava growing and consuming areas of Kenya and Nigeria, it was found out that 53% of the Kenyan children consumed inadequate protein while Nigeria, only 13% consumed inadequate protein due to better economic status of their households . These rates are high especially among the under five from and require urgent nutritional intervention.

Both cassava and soy bean are locally available, cassava is energy dense but protein deficient while soy bean contains good quality and is cheaper. Fortification of commonly consumed products, ugali and porridge will improve their quality thus provide nutrient dense diets for the children and entire households of Western Kenya.

1.3. Objectives

1.3.1. Broad objective

To investigate the effect of soy fortification on the proximate, functional and sensory characteristics of cassava cereal composite flours and products from Busia County

1.3.2. Specific objectives

1) To formulate and standardize cassava based soy fortified porridge and ugali flours and cooked products.
2) To determine the effect of soy fortification on the proximate composition of cassava based ugali and porridge.
3) To determine the effect of soy fortification on the functional properties of the cassava cereal composited flours.
4) To evaluate the sensory characteristics of porridge made from cassava based soy fortified flour

1.4. Hypotheses

Ho. Soy fortification of cassava based composite flours improves their nutrient density and functional properties significantly.

Ho. Soy fortified porridges will be acceptable to consumers

1.5. Significance of the study

This study is beneficial to various sectors ranging from the Ministries of Education, Agriculture, Health and individual households. The formulated flour provides options which when adopted in the schools for supplementary feeding will improve their class attendance and concentration. When children attend school daily and actively participate during lessons then their overall academic performance improves manifesting in good score in exams.

Findings of this study will contribute to knowledge and form a basis for other research studies on food fortification. As documented in the literature, there is limited information on fortification of local staples with legumes like soy bean for improvement of diets therefore more studies can be derived from the recommendation of the current study.

The Ministry of Health benefits from this study since the developed products when adopted will alleviate malnutrition and related ailments thus lessening expenses of malnutrition related conditions. The ministry would then use their funds to scale up other services and expand services to reach more communities for example malaria control.

The Ministry of Agriculture through extension services has extensively promoted soy bean among small holder farms making it one of the cash crops. Unfortunately consumption at households is still low despite its nutritional quality. This study aimed to promote consumption of soy together with cassava and thus complement the efforts of the Ministry. As a result farmers will have increased market for their farm produce. This will reflect in increased farm output therefore better income to purchase assets as well as other needs and investments, food and security status at households.

For households, consumption of soy fortified products will ensure members are well nourished thus falling ill less often in addition to alleviating PEM. The households will also spend less on medication for treatment of malnutrition related ailments thus will save and invest in assets and other income generating activities. Households that produce excess will also have a place to sell since the products can be processed on large scale for schools and food industries therefore generate more income.

CHAPTER TWO

LITERATURE REVIEW

This review examines the history of cassava, its utilization and nutritional quality which is a predisposing factor to Protein Energy Malnutrition (PEM) that manifests in children below five years of age. Statistics for malnutrition globally, nationally and for Western Kenya have also been elaborated. Soy bean nutritional quality and prospects for fortification of cassava based cereal composites in the effort to fight PEM among children of Western Kenya households through the principle of complementation.

2.1. History of Cassava

Cassava, *manihot esculenta crantz*, also referred to as *manioc, yucca, or mogo*, is a woody shrub of the euphorbiaceae family, native of South America (Montagnac, Davis & Tanumlhardjo, 2009). It is cultivated in tropical and subtropical regions for its underground starchy tuberous root (Olumide, 2004) that grows up to between fifteen to one hundred centimeters, with a mass of about a half to two kilograms (FAO, 2004). Cassava is the third largest carbohydrate source after rice and corn in Africa, Asia and Latin America (Ugwu, 2009).

According to FAO (2005), cassava was introduced into Africa in the 16th century by Portuguese explorers and traders from Brazil, from where it was spread by Africans to many other parts of the continent. Cassava replaced traditional staples like millet, bananas and yams because of the ease of its cultivation on fallow and marginal soils, drought and disease resistance, flexibility in planting and harvesting cycles and high output, making it a famine reserve crop. Approximately 75% of Africa's cassava output was harvested in Nigeria, the Democratic Republic of Congo, Ghana, Tanzania and Mozambique. It is anticipated that by 2020, over 60% of global cassava production will be from Sub-Saharan Africa (FAO, 2004). Nutritionally cassava provides a reliable and affordable source of carbohydrates for most of the households in sub-Saharan Africa (Hussein *et al*, 2012) which amounts to about 88% of all the cassava produced in this region (Falade & Akingbala, 2009).

2.1.1 Cassava Utilization

Cassava has been used to make numerous products worldwide, for instance in Latin America and the Caribbean; cassava is processed into starch and ethanol while in Europe it is channeled into animal feed production (Ahwage, 2013). In Africa there are about five groups of food products made from cassava (FAO, 2004) which include fresh or dried roots, pastry products, granulated products and cassava leaves. Fresh roots are commonly eaten raw, roasted in open fire, boiled in water or fried (Olumide, 2004). The dried products, both fermented and unfermented can be in the form of chips or flour which are used to make, *ugali* (a stiff porridge), porridge and pastries (Ugwuona, 2009).

African countries such as Nigeria process cassava into *lafun, gari, achicha, akpu* and *puraka*, which are pastry products enjoyed and consumed in most households (Akubor & Ukwuru, 2003). A number of cassava products are also consumed in Tanzania (Laswai *et al*, 2006): *Yake yake* is a product made from cassava paste after tubers are washed, peeled, grated, dried sieved to a meal, moulded and steam baked while *Agbeli kaklo* slightly differs from *yake yake* when pieces of meat are added before moulding and frying in palm kernel or coconut oil. The paste for a third product *Kibabu* is made from fresh cassava mixed with onions, salted, then fried. In Kenya, cassava is consumed as boiled or roasted snacks or is processed into pure flour or mixed with cereals like maize, sorghum and/or millet and prepared into porridge, *ugali* or other snacks and beverages (Mukui, 2003).

2.1.2. Nutrient Composition of Cassava

The nutritional value of cassava, like other roots and tubers is in its potential to provide one of the cheapest sources of dietary energy (Akubor &Ukwuru, 2003). As shown in table 2.1, cassava has the highest amount of carbohydrates but the least in all other nutrients compared to the other starchy staples. Furthermore, cassava is mostly consumed in the raw state rather than products made from its flour which is more nutrient dense. The bulk of raw cassava root is more than half (56% to 68%) moisture (USDA, 2002), therefore the remaining total solid matter is deficient in essential nutrients (FAO/IFAD, 2012), predisposing consumers to malnutrition (Ugwu, 2009). Unfortunately, cassava is the staple food for many households who depend on it for all their nutrient needs including protein and energy.

Table 2.1 Comparison of nutrient composition of cassava to other high energy staple foods

Food	Moisture	Protein	Lipids (g)	Ash	CHO	Dietary Fiber
Cassava root raw	59-68	1.36	0.28	0.62	38.06	1.8
Tapioca(flour)	15.20	1.20	0.6	2.50	78.30	2.20
Wheat	12.6	11.3	1.8	1.7	59.4	13.2
Rice	13.0	7.7	2.2	1.2	73.7	2.2
Corn	11.3	8.8	3.9	1.3	65.0	3.8
Millet	12.0	10.5	3.9	1.6	68.2	3.8

Source: Montagnac *et al,* 2009**;** Koehler & Weisser, 2013

2.1.3. Anti-nutritional Factors in Cassava

The cassava root is one of the plant foods that contain naturally occurring compounds that are potentially toxic. Sarkiyayi & Agar (2010) in their study established that cassava contained toxic nitrile (CN) compounds, 93% of which were in the form of Linamarin and 7% Lotaustralin, which are B-glycosides of acetone cyanohydrins and ethyl-methyl cyanohydrins, respectively. These authors attributed their harmful effect on humans to hydrogen cyanide which is produced through the breakdown of these Cyanogenic glycosides by an enzyme catalyzed process, cyanogenesis. These researchers also found that the compounds are more concentrated in the leaves, stems and the peels of the cassava tubers to protect the plant from pests and predators. Additionally, according to Falade and Akingbala (2009), the concentration varies according to the varieties, part of the plant, age, climatic and environmental conditions. The bitter variety normally has higher concentration of toxins than the sweet ones. Ingesting sufficient quantities of these compounds can cause acute intoxication resulting in nausea, dizziness, vomiting and death in some cases. Added complications include goiter and cretinism due to the toxins' effect on iodine absorption and utilization in the human body (Taiwo, Jimoh & Osundeyi, 2010).

In rare cases, these compounds have been reported to cause *konzo*, a disease that manifests by permanent lower leg paralysis (Nyanzi & Jooste, 2012). According to Chijindu and Boateng (2010), the safety of cassava products should be ensured through effective processing which involves cellular disruption combined with proper drying. Consequently, several processing techniques have been adopted to make cassava safe for human consumption by eliminating the toxins and to improve their shelf life (Ajani & Onwubuya, 2013).

2.1.4. Processing Cassava

The two main challenges related to utilization of cassava are perishability and the presence of cynogenic compounds that pose a health threat to humans if consumed without processing (Hussein *et al*, 2012)). Once harvested, the roots remain fresh only for about two days. Therefore to reduce post harvest losses, bulk and make cassava safe for human consumption, a number of methods have been developed for processing them (Udofia, Udoudo & Eyen, 2013). These include;

2.1.5.1. Fermentation

Fermentation is the process of exposing animal or plant tissues to micro-organisms to achieve desirable biochemical changes and significant modification in food quality (Eleazu *et al*, 2011). This process results in improved nutrient bioavailability, generation of B vitamins, desirable aroma that improves palatability of the food and improved storage stability (Aro, 2008). Fermentation with *Lb plantarum starter* cultures has been reported to significantly reduce cynogenic glycosides in cassava as well as inhibiting microbial activity that promotes food spoilage (Nyanzi & Jooste, 2012).

Aro (2008), further reports that fermentation specifically for cassava and its products can be done either of the two techniques. First is the liquid substrate or submerged technique where water is always in a free state with nutrients suspended or dissolved in it and microorganisms are inoculated to catalyze the process. The second is solid substrate technique which is a bio-system that consists of a solid porous water absorbing matrix of high water activity on glass or gas interface in which air freely circulates at low pressure within the fermenting substrate. These processes then allow break down of anti nutrients, improvement of nutritional quality as well as palatability of the cassava and products (Udofia *et al*, 2013).

2.1.5.2. Steeping in Water.

Soaking cassava in water eliminates toxins by dissolving them into the soaking water which is changed every eight hours for two days at room temperature (Ugwuona, 2009). According to Hussein *et al* (2012), the treatment involves a series of steps. First, the fresh tubers are peeled, washed and steeped in water for two days. They are then washed again, grated and re-steeped for another one day followed by de-watering, sifting, sun drying and then milling. This is the process that results in flour which can be used to process several other products.

2.1.5.3. Boiling

Parboiling of cassava chips enhances storage stability due to partial gelatinization of starch thus reducing its susceptibility to insect infestation. Chijindu and Boateng (2008) in their study on the effect of various processing techniques on the storage stability of cassava chips found that parboiled chips had the least number of insect infestations as well as the least weight loss after sixty nine days.

2.1.6. Protein Quality of Staple Foods

According to Guria (2006), tubers like cereals have low nutritional value for monogastric animals including humans. They are low in the indispensable amino acids such as lysine, tryptophan and threonine, and lysine is the most limiting amino acid. Roots and tubers, though rich sources of carbohydrates, are deficient of protein (Udofia *et al*, 2013). This poor quality of protein and low nutrient density (Ugwuona, 2009) has led to varied efforts to improve the nutritional value of cassava to reduce vulnerability of consumers to malnutrition.

2.2. Existing Strategies to Improve Nutrient Content of Protein Deficient Diets

Since tubers and cereals which are the main staples do not meet all the nutrient requirements for humans predisposing them to malnutrition (FAO/IFAD, 2012), there have been several advances to improve the diets of households especially those who depend entirely on plant sources for almost all their nourishment. Current strategies being used to address malnutrition include; improved dietary diversification, supplementation, bio-fortification of crops, staple foods fortification and complementation (Loech, 2014). Tontisirin and Bhattacharjee (2008) in their study found that community food based approaches are the best and sustainable means to eradicate malnutrition.

2.2.1. Dietary Diversity

Some households consume poor diets due to inadequate knowledge and skills on food selection and preparation (Chianu *et al*, 2008). According to Loech (2014), education can enable people to improve their nutrient intake when they are enlightened on what food to eat, how to prepare them, safely and even their cultivation. Kitchen gardening and keeping small animals has been emphasized during nutrition education as it leads to dietary diversity and better quality of diets at the household level. Dietary diversification and modification which are culturally acceptable, feasible and sustainable have the potential to prevent nutrient deficiencies in a population without the risk of antagonistic interaction that causes nutrient losses (Gibson, 2011).

2.2.3. Supplementation

Supplementation is the provision of one or more micronutrients daily or periodically in liquid, tablet or capsule, for example vitamin A capsules to children from 6 months or iron and folate tablets to pregnant women during the prenatal checkups (Loech, 2014). This is usually a solution to acute nutrition deficiencies and can produce immediate results while longer-term strategies are being developed (Tontisirin & Bhattacharjee, 2008). Micronutrient supplementation has been effective in fighting nutrient deficiencies in targeted populations (Shetty, 2011).

2.2.4. Bio-fortification

Bio-fortification is a sustainable and self sufficient agricultural means to fight malnutrition in resource poor rural populations in developing countries (Miller & Welch, 2013). According to Gibson (2011), bio-fortification of staples involves all strategies to enhance nutrient content and their bioavailability through breeding. Due to the poor quality of nutrients in staples, biotechnological advances have been adopted to genetically induce genes into these staple crops in order to improve their nutritional quality. Zinc, iron, calcium and vitamin A bio-fortification of staples has been found effective in addressing malnutrition in low income populations. For instance, in Brazil cassava has been bio-fortified with beta carotene resulting into cultivars with varying intensity of the carotenes that range from red to yellow in colour (Ferreira *et al*, 2008). Several other staple crops have been bio-fortified such as rice with zinc and pearl millet with iron in India (Loech, 2014). Orange fleshed sweet potatoes have been bio-fortified with pro-vitamin A and released into various African countries to fight vitamin A deficiencies (Miller & Welch, 2013).

2.2.5. Food Fortification

Fortification is the process of adding one or more nutrients to commonly consumed foods with the goal of increasing nutrient intake of a population that is at risk (Faber & Laurie, 2011). Processed foods have been fortified with one or more nutrients especially minerals and vitamins to address micronutrient deficiencies in targeted populations (Muller &Krawinkel, 2005). For example, table salt has been fortified with iodine to prevent iodine deficiency disorders (Miller & Welch, 2013). Food based fortification has also been promoted at processing level and community or household level that involves addition of proteins in form of amino acids into locally available staples during food processing and preparation to improve the quality of diets (Gibson, 2011). For example, lysine fortification of wheat flour significantly improved the weight and height of children in Pakistan (Hussain *et al,* 2004). In most food studies, tubers and cereals which are locally available have been used as the vehicle while legumes are the fortificant to add amino acids in order to improve the quality of diets.

2.2.6. Complementation

The combination of a cereal and a legume where one supplements the other with the limiting amino acids creating a mutual balance results in nutritional complementation (Serrem *et al,* 2011). Cereals are deficient of lysine but contain sufficient amounts of sulphur containing amino acids that are limiting in legumes (Kwabena *et al*, 2010). Food studies on complementation have shown that compositing cereal flours with legumes improves the protein quality of the cereals since the most limiting amino acid of starchy staples (lysine) is plenty in legumes thus making the product complete (Martin *et al*, 2010). Soy bean among other legumes has been outstanding in the improvement of the amino acid profiles of cereal based diets. This principle of complementation is the basis of the current study to improve the nutritional value of cassava based products.

2.2.7. Cassava cultivation in Western Kenya

Were (2010) reported that Busia one of the counties of Western Kenya, with about 50% of the population living below the poverty line. Residents practice agriculture though on poor soils resulting in low output to meet their food needs and provide income thus they have remained poor. Among the seven constituencies of Busia County of Western Kenya, farmers grow cassava both for household consumption and a source of income. According to IITA (2008) most of the farmers in Kenya who were selected in a 2006 study on cassava varieties and diseases were from Teso district which is currently part of Busia County. In a study by Mware *et al* (2009) on transmission and distribution of cassava brown streak disease in Kenya, several farms in Busia were selected. Some of these farms were located in Teso district. In Western Kenya, cassava is commonly consumed in households in form of ugali and porridge (Mukui, 2003). This can be singly or mixed with cereals like maize, millet or sorghum. This diet is depended on by the whole household including children under five years of age yet it is deficient in essential nutrients especially proteins.

2.3. Human protein requirements

Human beings of different ages and sex have different levels of requirements for protein based on their bodies' needs at a particular life stage as shown in Table 2.2. Comparing this protein needs with the protein contents of cassava flour (Table 2.1), it is obvious that the cassava based diets cannot provide enough proteins to meet their daily requirements therefore there is need to adopt strategies that improve the nutritional value of such diet.

Table 2.2 Protein requirements for humans based on age and sex

Children	Protein g / day	Adult females	Protein g/ day
1-3 yrs	13	10-12 yrs	44
4-6 yrs	28	13-15 yrs	54
7-9 yrs	31	16-17 yrs	56
Adult males		18-29 yrs	56
10-12yrs	43	30-59 yrs	56
13-15 yrs	61	60+ yrs	56
16-17 yrs	65		
18-29 yrs	65		
30-59 yrs	65		
60+ yrs	65		

Source: Rao (2009)

According to Rao (2009) it is important to provide the correct levels of protein as well as adequate calories to enable the body to utilize proteins for the specific more important role of body building rather than generating energy. Failure to achieve this would force the body to convert all the proteins, lipids and carbohydrates to energy resulting in growth retardation. Table 2.3 further shows the indispensable amino acid reference pattern for children from 1 year to adolescence and onset of adulthood at 18 years as recommended by FAO/WHO/ UNU (2007). It is evident that children require enough proteins from their diets to be able to provide the amino acids to meet the need of growth and maintenance of their bodies. Cereals and tubers which are staples on their own cannot provide this level of protein and cassava being the least protein source then require improvement therefore addition of legumes especially soy bean results in better nutritional value.

Table2. 3 Indispensible amino acid requirements for children on daily basis

Age	Histidine	Isoleusine	Leucine	lysine	Threonine	Tryptophan	Valine
1-2yrs	15	27	54	45	23	6.4	36
3-10 yrs	12	23	44	35	18	4.8	29
11-14 yrs	12	22	44	35	18	4.8	29
15-18	11	21	42	33	17	4.5	28
>18 yrs	10	20	39	30	15	4	26

Amino acid requirements for children and adolescents (male and female combined) in mg/kg/day according to age .Source: FAO/WHO/ UNU, 2007

The human body is 15% protein; since body structure, membrane and organelles are made of proteins (Smolin & Grosvenor, 2010). For instance, protein and calcium are the main components of the bone structure (Tome, 2010). Other functions of proteins in the human body include promoting growth and maintenance, transport, regulation of metabolism, providing energy when carbohydrate and lipids are not sufficient, regulation of body fluid balances and immunity, among others (Gropper, Smith & Groff, 2009). For protein to perform all these functions, it must be obtained from the diet in sufficient amounts.

For the human body to function effectively, diets must contain high quality protein at the required quantity and quality particularly for children who still need to build basic body structures for effective growth and maintenance (Bwibo & Neumann, 2003). Children become predisposed to malnutrition due to poor quality of proteins in their diets (Cheah *et al*, 2010). Diets in low income households are predominantly starch with little or no animal sourced protein foods (Neumann & Bwibo, 2002). As a result, children's growth and cognitive development is altered resulting in stunting and incompetence in adulthood making them fail to achieve their dreams due to their limited potential (Muller & Krawinkel, 2005) and low cognitive capacity (Ziegler, 2011).

2.3.2. Protein Deficiency in children

Malnutrition is a clinical condition that includes several overlapping characteristics such as growth failure in children and muscle wasting in adults due to inadequate supply of nutrients to the body (Cheah *et al,* 2010). PEM is the major type of malnutrition that results from under nutrition mostly manifesting in children in the developing world (Muller & Krawinkel, 2005). According to Ziegler (2011), 17.1 million children were stunted globally while twenty million were severely wasted by the year 2010. Malnutrition is the key risk factor for about one third of all deaths of children under five years globally (UNICEF, 2009). These high rates of malnutrition and the resultant deaths slow down the development process in many African countries due to increased expenses on medication and management of malnutrition and related infections.

According to Muller and Krawinkel (2005), PEM in children is defined as measurements that fall below two deviations from normal weight for age (underweight), height for age (stunting) and weight for height (wasting). This manifests in severe wasting with or without oedema. Marasmus is the severe wasting without oedema while kwashiorkor is manifested by wasting with bilateral eodema that is characterized by bloating due to fluid retention on both sides of the body. In some cases a combination of wasting and eodema may occur in one patient, a condition referred to as marasmic kwashiorkor (Haddad, 2013). The word *kwashiorkor* originated from Ghana where it meant the "disease of a displaced child". This displacement is in the sense that another pregnancy has occurred or a sibling borne (Gropper *et al,* 2009).

2.3.3. Protein sources in the diets of Kenyan households

According to Bwibo and Neumann (2003), diets in Kenyan households are mainly cereal based comprising of white maize, sorghum, millet and tubers with some fruits and vegetables which are available seasonally. This is common in almost all developing countries where over 70% of dietary proteins are supplied by cereals that are relatively poor sources of protein (FAO/WFP/IFAD, 2012). These cereals also contain phytates which makes the nutrients less bio- available predisposing children PEM (Anuonye, 2011).

Animal source proteins which are the best proteins (Smolin & Grosvenor, 2010) on the other hand are rarely consumed even in households that keep small animals and cattle. Meat and eggs were consumed once to thrice a month in most households despite the fact that some of them kept poultry and small animals (Bwibo &Neumann, 2003). Low income households cannot provide animal sourced protein foods to their families daily since they are unaffordable or sale to obtain cash for other uses (FAO/IFAD, 2012).

According to FAO (2003) communities along the lakes and ocean like those in Busia do not consume as much fish as expected. For example, communities living around Lake Victoria obtain only 25-30% of their daily supply of protein from fish which is insufficient when expressed as a protein score because it is less than the required 65%. There increased demand for fish in the international market has further increased prices. Omena for instance which is low cost and highly nutritious is now expensive because of the increased demand for fish meal and chicken feed. This makes them scarce in the markets and household diets as well.

2.3.4. Nutritional status of children in cassava growing areas

Regular consumption of cassava which is deficient in other essential nutrients (Akoja & Mohammed, 2009) predisposes communities to malnutrition especially in children whose protein needs are very high (Tome, 2010). A comparative study by Stephenson *et al* (2010), on adequacy of protein intake by children in cassava consuming areas of Kenya and Nigeria showed that children from both countries had inadequate intake of protein at 53% and 13%, respectively. These manifested in stunting in both populations showing that these had been experienced for a long time. Dietary diversity scores for both populations were less than 4.5. This inadequate intake of protein therefore made them vulnerable to malnutrition. Children selected for this study in Kenya included those of with two divisions that fall within Busia County of Western Kenya. To improve the quality of cassava based diets and other starchy staples, compositing with legumes has been recommended as a sustainable approach to alleviating malnutrition among vulnerable communities (FAO/WHO, 1994).

2.4. Soy bean

Soy bean *glycine max* is a legume that thrives well in many parts of the world (Chianu *et al*, 2009). Among the legumes, it is the most nutritious with a protein content equal to animal sourced proteins (Martin *et al*, 2010). Soy bean production has been promoted in many developing countries as a cheap source of protein. These beans have been used in various forms for fortification of cereals and tubers resulting in nutrient dense products that can be adopted to alleviate PEM (Bunereka & Mahendran, 2009). This makes it preferred in many areas for improvement of the protein quality and quantity of diets.

2.4.1. Soy utilization

According to Smolin and Grosvenor (2010) soy based foods are available in many forms. Soy can be eaten whole boiled or roasted, as sprouts added to salads, soy butter which is similar to peanut butter for spreading on crackers and sandwiches, *tofu* also known as bean curd, fermented products such as *miso* and *tempeh* among others. Soy flour can also be incorporated into baked products, made into Texturised Soy Protein (TSP) for vegetarian burgers, hot dogs, meatballs or be used as extenders and fillers. Other soy products include soy milk, soy yoghurt and cakes (Balogun *et al*, 2012). In addition it has been used in many instances where cereals have been composited with soy bean to create a balanced amino acid profile of household diets and supplementary diets.

2.4.2. Nutritional value of soy bean

Soy bean among other legumes contains the highest amount of protein of between 38-40 grams per one hundred grams (Anuonye, 2011), its extraction residue represents more than 40% of utilization value of the beans. These proteins are highly digestible too. A digestibility study by Serrem *et al* (2011) using a rat bioassay showed that soy bean protein is highly digestible and comparable to animal sourced proteins. Table 2.4 shows the high protein content in soy beans making them rich sources of proteins. This are distributed at different proximate percentages in the cotyledons, hypocotyls and the hull having the highest percentage content. The whole bean is approximately 40% protein.

Table 2.4.Nutrient content of different parts of the soy bean

Component	**% protein**	**% fat**	**% CHO**	**% ash**
Whole	40	20	34	4.9
Hull	43	23	29	5
Cotyledons	8	1	86	4.3
Hypocotyls	41	11	43	4.4

Source: Chianu *et al* (2008)

2.4.3. Anti-nutritional factors in soy beans

According to Ari *et al* (2011), raw soy bean contains anti-nutritional factors which interfere with the intake, bio-availability and metabolism of some nutrients by monogastric animals thus lowering its acceptability and nutritional value. These factors are heat labile therefore heat treatment inactivates them. They include Trypsin inhibitors, lectins, goitrogens, phytates and heat stable oligosaccharides. Fermentation reduces the anti-nutritional factors to minimum utilizable levels (Eleazu *et al*, 2011). This therefore makes it necessary to process soy bean before use in fortifying tubers and cereals to enhance availability of the protein through elimination of anti-nutrients. This can be effectively controlled by using appropriate preparation methods such as soaking, thermal treatment, germinating and dehulling to make nutrients more bio-available (Bunereka & Mahendran, 2009).

2.4.4. Health benefits of soya bean

In a review by Smolin and Grosvenor (2010), soy products have been a major source of protein in countries with less prevalence of heart disease like Japan and China. Soy protein, its isoflavones and phytochemicals are believed to be responsible for the low incidents of cardiovascular diseases in Asian countries. Its isoflavones are estrogen-like therefore responsible for reduction of menopause symptoms and prevention of bone loss. Soy is also believed to have beneficial effects in preventing and treating certain forms of cancer. In addition, soybean has a low glycemic index providing a steady source of energy therefore is good in regulating of blood glucose and weight management (Martin *et al*, 2010).

2.4.5. Fortification of Starchy Staples with Legumes and other Oil Seeds

In their study, Awasthi *et al* (2012), developed soy fortified biscuits for supplementary feeding of children and determined their proximate and sensory qualities. At 20 % soy bean substitution, protein content of the biscuits increased from 7.31 % to 9.38%. In another study by Bunereka and Mahendran, (2009), cereal snack (wheat biscuits) fortified using soy was formulated and its quality characteristics evaluated. The researchers found out that that biscuits with 25% soy flour substitution contained 14.2% protein up from 5% and were good enough for supplementation to fight PEM among children in Sri-Lanka.

Apart from cereals, tubers especially cassava has also been fortified with legumes and oil seeds to improve their nutrient content. In a study by Akoja and Mohammed (2009), cassava flour was replaced with pigeon pea flour at varying percentages. Fortification at 20% increased the protein content of *fufu* from 3.1 % to 13.7% and was also acceptable for consumption. Falola *et al* (2011) fortified cassava biscuits with cucurbita seed flour at different levels found that the protein content of biscuits increased from 2.1% to18.1% at as low as 10% inclusion of cucurbita into the cassava biscuits. In most of these studies soybean has proved to be more superior and effective among other legumes in improving the protein quality of diets. Balogun *et al* (2012) used defatted soy bean flour to fortify tapioca flour and at 20 % soy fortification, protein content of the tapioca meal increased by 9.73%.

2.4.6. Soy utilization in Western Kenya

Soy bean was introduced in this region to improve the diets of the communities by including it in their diets as well as a source of income when the extra would be sold to generate some income (Mahasi *et al*, 2008). As a result has been the leading producer of soy bean in the country since 2003 though its consumption in the diets is still low (Chianu *et al*, 2008). According to Chianu *et al* (2009), this is because the communities are ignorant of the nutritional quality of soy bean, lack skills for preparation of the bean to make it more palatable as well as the fact that it takes more time to boil therefore is fuel inefficient compared to other beans . Since malnutrition is still prevalent in this region it is important to promote its utilization in the diets together with their staples to improve the quality of diets in households. As a legume, soybean boosts soil fertility by fixing atmospheric nitrogen which is an essential plant nutrient that is lacking in most Kenyan soils in addition to its nutritional value. This has lead to the increase in adoption of improved soy bean varieties especially TGx series to improve marginal soils and increase crop yields. Soybean has also been reported to work against *striga,* a stubborn maize parasite when the two are intercropped (Chianu *et al*, 2008).

2.5. Reactions in Foods that cause Nutrient Losses

In his review, Blackwell (2006) reported that nutrient loss from foods may result from exposure to heat, some level of moisture content and a high pH range. For example, maillard browning a chemical reaction between an amino acid and a reducing sugar takes place in conditions of high temperature (≥100^0 C heat), low moisture and alkaline environment. Intermediates are formed leading to flavuor compounds and melanoidin pigments. However, though the foods become more appealing, it does have implications for loss of essential amino acids (lysine, cystine and methionine), formation of mutagenic compounds and the formation of compounds that that can cause protein linking implicated in diabetes.

According Montagnac *et al* (2009), the B vitamins contained in cassava roots are lost during processing. Analysis of the nutrient retention of the edible parts show that raw and boiled cassava keep majority of the high-value nutrients except riboflavin and iron. For instance *gari*, one of the products that involves grating, fermenting and roasting is least efficient in nutrient retention.

2.6. Evaluation of Soy Fortified Food Products

A food product may be subjected to various chemical, functional and sensory tests to ascertain its overall quality.

2.6.1. Functional Characteristics of Flour.

Functional properties of flours or products determine their application and use in the manufacture of various products (Adeleke & Odedeji, 2010). According to Ashogbon & Akintayo (2013), starches of different cereals have uniqueness in their chemical composition, morphologies and functionalities. This is due to the difference in the amylose /amylopectin ratio, genotype, soil type during growth and the intensity of radiation of the sun during growth. Cereals have lower amylose content and smaller granules which promote their use in food processing as they give the smooth texture which makes the products more palatable. In addition the whiteness, bland flavuor ease of digestibility especially for rice stands out when compared to other cereals and legumes. Legumes on the other hand have higher amylose content and thus undergo retrogradation and syneresis which limit their application in the food industry. These unique qualities determine how flours or food products behave under certain conditions and eventually the use of flour from particular cereals in processing of certain food products.

Water absorption of flour is determined by its cohesiveness. Cohesiveness of flour is promoted by the presence of protein which is responsible for the uptake of water (Adenekan *et al,* 2014). According to Falola *et al* (2011), water absorption capacity is a key factor for bulking and consistency in addition to determining the use of the flour in bakery. Proteins absorb water up to 200% of their weight whereas carbohydrates absorb only 15% of their weight. Therefore flour that has higher protein content is expected to absorb more water than one that has less protein. In their study, Akubor and Ukwuru (2003) found out that soy fortification of cassava flour increased water absorption capacities of the composited flours.

The mechanism of fat absorption of a sample in addition is attributed to the physical entrapment of oil and binding of fat to the polar of proteins (Adenekan *et al*, 2014), hence a sample that has more protein should trap more oil and thus have a greater fat/oil absorption capacity. Oil/fat absorption capacities are key characteristics required of flour as they determine its hydration in formulation of products such as ground meat formulation (Adeleke & Odedeji, 2010). Oil absorption of the flour during preparation of food products positively influences the mouth feel or texture of a product and hence its acceptability (Falola *et al,* 2011). In their study, Akubor and Ukwuru (2003) found that soy fortification of cassava flour increased its oil absorption capacities.

Bulk density on the other hand describes the degree of flour to compact together in order to reduce volume and the space it occupies (Akubor &Ukwuru, 2003). It is essentially the measure of the degree of coarseness of sample flour (Ashogbon & Akintayo, 2013). This is an important factor in determining the packaging requirements and space, material handling and application in wet processing in the food industry (Adeleke & Odedeji, 2010). Flours to be used for supplementary feeding of populations are selected on the basis of how much of it can occupy the least possible space to economize on storage space and packaging materials. Adeleke and Odedeji (2010) in the studies found that addition of sweet potato flour into wheat flour decreased its bulk density from 7.47g/cm^3 to 6.83g/cm^3 on addition of 25% sweet potato flour.

Viscosity is a measure of the intrinsic ability of a fluid to resist flow under force and is quantified as the ratio of shear stress to shear rate (Kim, 2007). It is a key parameter used in determining the quality of starch based products as it gives an idea of the ability of a material to gel after cooking (Taiwo *et al*, 2010). This is basically determined by the starch content and the percentage of amylopectin to amylose starch content of a cereal (Ashogbon & Akintayo, 2013). According to Masters, Garcia and Chambers (2013) there has been a need among speech – language pathologists and dieticians to determine the right consistency of modified and prepared fluid during care of their dysphasia patients. For a long time they have used the stir, spoon and plop method which cannot be standardized as consistency of fluid by visually representing flow distance across a flat surface. They experimentally found the linespread method to be accurate and more reliable than the latter. Mark and Nicosia (2007) used the linespread test to categorize liquids and concluded that the linespread test is a useful tool in broad categorization of fluids into therapeutically significant grouping and is also cost effective. According to Kim (2007) the line spread test measurements show a significant inverse relationship with the viscometer scale. This is because as a liquid becomes more viscous, the distance from the center is reduced while on the viscometer it reads a higher centipoises value.

2.6.2. Sensory evaluation

According to Blackwell (2006), Sensory evaluation is the scientific discipline that is used to evoke, measure, analyze and interpret reactions to those characteristics of foods and materials as perceived by the senses of sight, smell, taste, touch and hearing. This evaluation is done using a descriptive panel that identify, quantify and differentiate the sensory attributes of a food as well as a consumer panel that test acceptability (Lawless &Heymenn, 2010). This is essential since a product developed must first be acceptable by the target vulnerable group in order to be used in a nutrition intervention program. Balogun *et al* (2012) evaluated the colour, aroma, texture taste and overall acceptability of tapioca- soy meal using a ten member panel. For all these sensory characteristics, the average scores increased with increase of defatted soy in the meal. For example, the aroma of plain tapioca was ranked 5.8 while tapioca soy meal at 20 percent soy fortification was ranked 7.3. Abiodun and Oladapo (2010) in their study evaluated colour, odor, texture and overall acceptability of a stiff dough made from yam flour that was substituted with cassava starch and soy flour at different ratios. In their findings, plain yam stiff dough had the least score of 3.1 for overall acceptability while the treatment with 15% cassava starch and 15% soy bean scored highest overall with a value of 8.8.

2.7. Summary of literature reviewed

Based on the literature reviewed, it is evident that malnutrition exists in Kenya (KNBS, 2010; KDHS, 2015). The rates varied in the different livelihood zones across the nation (Nzuma & Ocholla, 2012). Malnutrition rates increased in Western Kenya (KNBS, 2015) indicating a need for intervention. Cassava is grown and utilized in the area (Mware *et al*, 2009; IITA, 2008) and soy bean too (Mahasi *et al*, 2008) though utilization at households is still low at households (Chianu *et al,* 2009)

Studies on cereal and tubers have shown that complementing them with soy bean improves their nutritional quality especially for proteins and work well in alleviation of PEM (Awasthi & Mohammed, 2011; Bunereka &Mahendran, 2005; Serrem et al, 2011; Ugwuona, 2009). Therefore since both soy bean and cassava are locally available, they can be combined to complement each other thus provide new and better quality of nutrient patterns for preschool children of Western Kenya.

This literature then justifies the use of both cassava and soy bean to complement each other since they are locally available according to recommendation by Anuonye (2011) and FAO/WHO (1994). There is limited information on fortification of staples using commonly consumed dishes in this region. Since cereal studies have shown that fortifying tubers and cereals with legumes significantly improved the protein content and overall quality of diets, there is need to fortify the diets of   households as well.

CHAPTER THREE

MATERIALS AND METHODS

3.0. Sources of materials

Dried cassava pieces, soy bean and the cereal (maize, sorghum and millet) grains were purchased from the Eldoret municipal market in Kenya.

3.1. Methods

3.1.1. Processing of the flours

Dried cassava pieces, soy bean, sorghum, millet and maize grains were each sorted and cleaned to remove extraneous material. Soy bean flour was prepared using the method by IITA (1990) with slight modifications. The soy beans were washed and parboiled for 20 minutes. They were then roasted in an oven at 100-120^{0}C for one and a half hours and cooled. The dry roasted beans, dried cassava and cereal grains were each milled separately using a commercial hammer mill (Powerline®, BM-35, Kirloskar, India) fitted with a 2.0 mm opening screen.

3.1.3. Formulation of the flours

Three cassava based composite flours were formulated by replacing cassava flour with the cereals (maize, sorghum and millet) at the ratio of cassava: cereal, 60:40. To produce six fortified variations from the composites, the three flours were substituted with soy meal at ratios of 30% and 50%. An additional three samples were formulated by maintaining a 100% cassava flour sample and producing two fortified variations by substituting cassava flour with 30% and

50% soy meal. Therefore, 12 samples were formulated for the study as shown in Table 3.1.

Table 3.1 Cassava based composite flours at different ratios of soy fortification

Flours/composites	Composite Ratio	Soy Fortification (Composite: Soy)	
		70:30	**50:50**
Cassava: Maize	60:40	Cassava: Maize: Soy	Cassava:Maize:Soy
Cassava: Millet	60:40	Cassava: Millet: Soy	Cassava:Millet: Soy
Cassava: Sorghum	60:40	Cassava:Sorghum: Soy	Cassava:Sorghum: Soy
Cassava	100	Cassava: Soy	Cassava: Soy
Maize	100		
Millet	100		
Sorghum	100		

3.2. Experimental design

In this study, several experiments were conducted using different experimental designs. The chemical and functional tests were done in triplicate for each of the samples and the mean used as the final result. In these two experiments, the Complete Randomized Design (CRD) was adopted.

During the descriptive sensory evaluation, the Randomized Complete Block Design (RCBD) was used to set the experiments. The samples were the treatments tasted by panelists thrice each at different sessions and setting making three blocks. While during the consumer evaluation a CRD approach was used where the panelists tasted the randomly arranged and coded samples once in one sitting for acceptability.

3.3. Sample preparation

3.3.1. Preparation of porridge

Porridge was prepared using the following method described by Gomez *et al* (1997) with slight modifications. It was prepared at 12.5% solids where 80 g of sample flour and 640 g of water were used. Half of the water was poured into a pan and allowed to boil while the rest was poured into a bowl containing the flour and stirred to make uniform slurry. This was then poured into the boiling water and stirred until it was completely gelatinized. Immediately the porridge started boiling, the heat was reduced slightly and a timer set to allow cooking for 20 minutes with regular stirring to avoid burning at the bottom. The porridge was then removed from the heat and maintained at 60^0C, the temperature at which viscosity was measured. The rest of the porridge was poured in a thin layer onto a flat tray and dried in an oven at 100^0 c for 2 hours. The drying process was completed in the sun for 6 hours, ground into fine particles using a food mixer (Kenwood® chef mixer KMC 200, Kenwood, United Kingdom) operated at medium speed for 5 minutes, packed in transparent polyethylene zip lock type bags and stored at 4^0C until required.

3.3.2. Preparation of *ugali*/ stiff porridge

Ugali was prepared using the following method of stiff porridge as described by Onyango (2014). A sample of 80 g flour and 160 g water, at a ratio of 1: 2, was used. The water was heated in a saucepan to boiling point. The flour was added gradually into the boiling water while stirring with a wooden cooking stick until it formed a stiff paste. The saucepan was then covered with a fitting lid and the mixture allowed to cook for 10±5 minutes with regular turning at intervals of 1-2 minutes. The stiff paste was removed from the fire, allowed to cool in the saucepan then divided into small pieces, which were spread onto a flat tray and dried in an oven at 100^0C for 2 hours. The ugali pieces were further sun dried for 5 hours and milled into fine particles using a food mixer (Kenwood® chef mixer KMC 200, Kenwood, United Kingdom) operated at medium speed, for 10 minutes packaged in air tight plastic zip lock bags and stored at 4^0C until required.

3.4. Proximate analyses

3.4.1. Moisture content

Moisture content of both porridge and ugali were determined using the oven-drying procedure (AOAC International, 1995) Method 934.01. About 2 g of the samples were dried in the oven (model UNB 300, by Memmert ® Gmbh & co.KG Germany) at 105^0C for 3.5 hrs, then cooled in a desiccator and weighed. Moisture content was obtained by calculating loss in weight as a percentage of the initial weight.

3.4.2. Crude Fat

Crude fat was determined using Soxlet extraction (AOAC International, 1995) Method 920.29. Samples of 2 g pre-dried ugali/ porridge were weighed into an extraction thimble and fitted into an extracting column. Fat was extracted for 8 hours using petroleum ether (40-60^0C). The extract was then dried in an oven at 105^0C for 30 minutes, cooled in a desiccator and weighed. Total fat was obtained by calculating the change in weight of the flask then expressing it as a percentage of the initial weight.

3.4.3. Crude Protein

Crude protein content (N×6.25) was determined by Kjedahl digestion process, AOAC International (1995) Method 992.23. The sample (0.3 g) was weighed into a digestion flask, 0.5 g of selenium catalyst and 25 ml of concentrated H_2SO_4 was added and shaken to mix and placed in the heating block (Model DK series 20 digester unit, 115 V / 50 - 60 Hz, by VELP Scientifica Srl, Italy) at 370-400^0C for about 60-90 minutes or until the contents turned clear. Then 0.2 ml of the digested sample, 5ml of a previously prepared N1 mixture (i.e. 34 g sodium salicylate, 25 g sodium citrate, 25 g sodium tartrate and 0.1 g sodium nitroprusside) was added and allowed to stand for about 15 minutes before 5ml of N2 mixture (i.e. 30 g sodium hydroxide and 10 ml sodium hypochlorite) was added. The mixture was allowed to stand for one hour during which it developed a blue colour whose absorbance was read off a spectrophotometer (Spectronic 21D AKIU®, Milton Roy, Germany) at 650 nm. The absorbance values were used to read off the %N from a graph plotted using standards (Okalebo, Gathua, & Woomer, 2002). The %N in the sample was calculated using the formula:

$$\%\ \text{Nitrogen} = \frac{(\text{a} - \text{b})\,\text{x}\,\text{v}\,\text{x}\,100}{1000\,\text{x}\,\text{w}\,\text{x}\,\text{al}\,\text{x}\,1000}$$

Where

a = Concentration of N in the solution

b = Concentration of N in the blank

v = Total volume at the end of analysis procedure

w = Weight of the dried sample and

al = Aliquot of the solution taken.

The crude protein was then attained by multiplying the % nitrogen by a factor (6.25).

3.4.4. Ash content

Ash content of the samples was determined by (AOAC International, 1995) Method 923.03. Two (2.0 g) of each sample were weighed into a previously dried and weighed porcelain crucible and burnt in a Muffle furnace (Carbolite®, 530 2 AU, Bamford, Sheffield's England) at 600^0C for 6 hours. The ash content was obtained as weight of the residue expressed as a percentage of the initial weight of the sample.

3.4.5. Energy Content

Energy content was determined by multiplying the mean values of crude protein, crude fat and total carbohydrate by their Atwater factors of 16.736 kJ, 37.656 kJ and 16.736 kJ respectively, taking the sum and the results were expressed in kilojoules per 100 g sample (FAO, 2003).

3.4.6. Carbohydrate content

Carbohydrate content was determined by subtracting the sum of weights of protein, lipid and ash from the total dry matter (FAO, 2003).

$$\mathbf{(CH_2O)_n = Organic\ matter\ (\%) - \{Protein\ (\%) + Lipid\ (\%) + Ash\ (\%)\}}$$

3.5. Functional tests

3.5.1 Water Absorption

The water absorption capacity was measured using the method described by Sosulsky (1962) with some modifications. Ten (10) milliliters of distilled water was added into 1 g of sample flour in a weighed 10 ml centrifuge tube. The tube was shaken manually for 2 minutes then centrifuged (Rato-uni®, model NR 7793 by BHG Germany) at 4000 rpm for 20 minutes. The liquid decant was collected and measured as well as the new weight of flour and the water absorbed. The difference between the new and the previous weight was used to calculate water absorption, which was expressed as the weight of water bound by 100 g of dried flour.

3.5.2. Viscosity

Viscosity of the porridge samples was compared using the line spread test (McWilliams, 1989). The line spread comprised a sheet of paper on which a two inches diameter hollow cylinder was used to make the first circle. From this circle, concentric circles were drawn at 0.5 cm intervals until 6 cm, and then placed under a clear glass plate. The cooked porridge samples prepared at 12.5% solids were maintained at a temperature of 60^0C by placing in hot water and constantly changing the water. The porridge (10 mls for each sample) was then poured into the hollow cylinder placed on the glass. The cylinder was lifted and the porridge allowed to spread for one minute. Data for the line spread were obtained by reading the distance the sample had spread at four radii, measured at right angles and calculating their mean. The larger mean radius was indicative of a less viscous sample. These were done in triplicate for each of the 12 porridge samples. Figure 3.1 illustrates measurement of porridge viscosity using the line spread test.

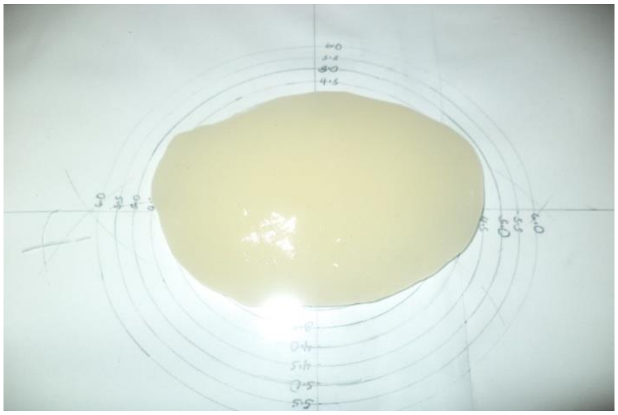


Figure 3.1: measurement of porridge viscosity using the line spread test (source Author, 2015)

3.5.3 Fat absorption capacity

Fat absorption capacity was determined using the method described by Sosulsky (1962). Ten milliliters (10 ml) of refined oil was added to 1 g of flour in a weighed 10 mls centrifuge tube then shaken manually to mix for two minutes. It was then centrifuged (Rato-uni®, model NR 7793 by BHG Germany) at 4000 rpm for 20 minutes and the volume of free oil recorded and decanted. Fat absorption capacity was then expressed as milliliters of oil bound by 100 g of flour.

3.5.4 Bulk density

Bulk density was determined using the method of Wang & Kinsella (1976). Ten milliliter (10 ml) measuring cylinders were filled to the mark with flour samples, and then gently tapped onto the laboratory bench until there was no further reduction in volume. The new volume of the samples was recorded for each of the triplicate tests. Bulk density (g/cm^3) of the samples was calculated as weight of flour (g) divided by flour volume (cm^3).

3.6. Sensory evaluation

Sensory characterization and consumer acceptability tests were conducted for 8 samples of porridge prepared from the plain cassava based composites and their equivalents fortified with soy at 30% and 50%. The eight samples were cassava: soy 70:30, cassava: soy 50:50, cassava- maize at 60:40, cassava- maize: soy 70: 30. Cassava- maize: soy 50: 50, cassava millet 60: 40, cassava millet: soy 70: 70 and cassava- millet: soy 50: 50.

3.6.1 Porridge sample Preparation

Porridge samples for both the descriptive and consumer acceptability studies were prepared using the method of Gomez et al, 1997 as described in chapter 3 section 3.3.1. The temperature of the samples was maintained at 60^0C by keeping them in a hot water bath and regularly replacing it with hot water throughout the tests.

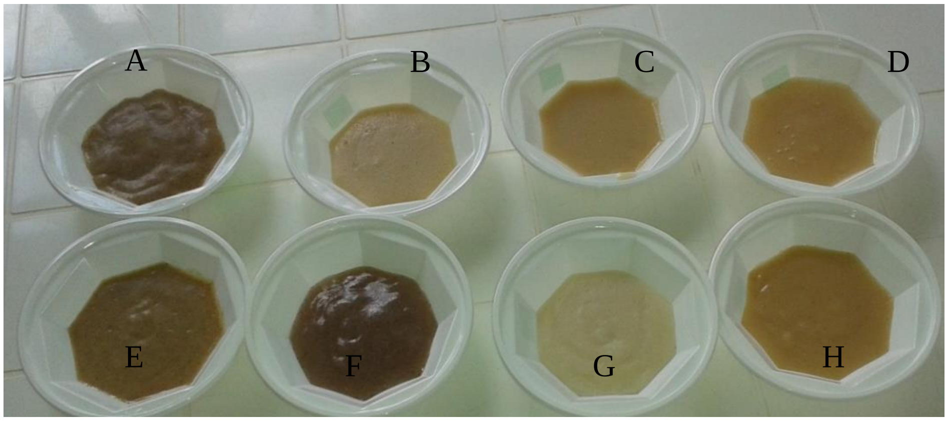


Figure 3.2 Porridge samples for descriptive and consumer sensory evaluation (Source Author, 2015)
A= cassava-millet soy 30% (CMiSB1), B= cassava- maize soy 30% (CMSB1), C= cassava-maize soy 505 (CMSB2), D= cassava soy 30% (CSB1); E= cassava millet, F= cassava-millet soy 50% (CMiSB2), G= Cassava maize, H= cassava soy 50% (CSB2).

3.6.2 Descriptive Sensory Analysis

3.6.2.1 Recruitment and screening of panelists

The number of panelists recruited for the study was 10 consisting of five males and five females whose ages ranged from 22 to 38 years and who were students or employees of the University of Eldoret. Recruitment was done through advertisements placed on the University notice boards to invite those interested, to participate in the evaluation of soy fortified porridge. A total of thirty people who responded to the advert were invited to the introductory session to familiarize them to the study and make a formal application. Using the application results respondents were screened for availability, smoking and allergies. Further screening included the basic taste test for sweet, bitter, salty, sour and *umami*, ability to identify differences in sensory attributes of porridge samples and flavour identification tests for six flavours namely, caramel, orange, pineapple, chocolate, lemon and almond as well as characterizing four samples of porridge in their own terms. The best ten panelists were selected for training and evaluation.

3.6.2.2 Panel training

The descriptive sensory panel was trained for eight sessions each lasting 2 hours for 2 weeks. They were trained on the skills of identifying, quantifying and differentiating the various sensory attribute of porridge samples. During the training, the panelists generated and agreed on 23 descriptors with their definitions for evaluation of the 8 porridge samples, selected suitable references and anchored them on a ten point scale for each of the descriptors (Lawless & Heymenn, 2010). The panel also had three trial evaluations to test their level of agreement.

Figure 3.3 Training session of the descriptive panel (source Author, 2015)

3.6.2.3 Evaluation of porridge samples

Evaluation of the porridge samples was done in triplicate over a period of three days in three sessions of one and a half hours each following a Randomized Complete Block Design. All eight porridge samples were randomly presented to each panelist during each session. A set of four samples was first evaluated, followed by a twenty minute break before the next set of four to avoid fatigue. The samples were presented in white disposable plastic bowls 7 cm diameter with 15 ml of porridge labeled with three digit codes on a tray with a glass of water, carrot cubes to cleanse the pallet, four tea spoons, one for each porridge type, a serviette and a print out of the ballot sheet. The reference samples were available at a common location labeled with the descriptors they represented throughout the evaluation.

Figure 3.4 Tray set up for descriptive sensory panel (source Author, 2015)

Table 3. 2 Descriptive sensory evaluation attributes definitions, references and rating scale

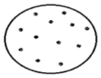
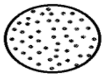
Attributes/ descriptors	Definitions	References to clarify rate the perceived sensation	Rating scale
Appearance			
Colour	Perceived coluor intensity of porridge, from white to dark to light	Fresh milk rated (1) and millet porridge rated (10)	Not dark =1 Very dark =10
Specks	Quantity of dark coloured specks visible on porridge	 5=  10=	Few = 5 Many = 10
Aroma			
Roasted soybean aroma	Intensity of aroma associated with roasted soy beans	Roasted soybean rated at (10)	Not intense= 0 Very intense= 10
Beany aroma	Intensity of an off aroma that is a characteristic of beans.	Raw milled soy bean at (10) Cassava porridge at (0)	Not intense=0 Very Intense =10
Nutty aroma	Having the aroma as that of roasted peanuts	Groundnuts rated at (10) Maize meal porridge at (0)	Not intense =0 Very intense=10
Cooked cassava aroma	Intensity of aroma associated with cooked cassava	Boiled cassava rated at (10)	Not intense =0 Very intense=10
Texture			
Coarseness	Extent to which grittiness or graininess of the porridge caused by small particles could be perceived.	Roughly milled maize rated at (10), corn flour porridge at 0	Not coarse =0 Very coarse= 10
viscosity	Force required to draw a liquid from a spoon over the tongue	Maize meal porridge rated at 10, cassava porridge at 0	Not viscous=0 Very viscous=10
Flavour			
Bitterness	Fundamental taste of which caffeine is typical	Strong coffee (20%) rated at 10,cassava porridge at 0	Not bitter=0 Very bitter =10

Table 3.2 Descriptive sensory evaluation attributes definitions, references and rating scale cont…

Attributes/ descriptors	Definition	References to clarify rate the perceived sensation	Rating scale
Astringent	Chemical sensation associated with puckering of tongue caused by substances such as tannins	Whole meal bread rated at 10,fresh milk at 0	Not astringent=0 Very astringent=10
Bland	Lacking taste, flavour or tang	Cassava porridge rated at (10), 20% citric acid at 0	Not bland=0 Bland= 10
Cooked maize taste	Intensity of the taste associated with cooked maize meal porridge	Maize meal porridge rated at (10), fresh milk at 0	Not intense =0 Very intense =10
Cooked millet taste	Intensity of the taste associated with cooked millet porridge.	Millet porridge rated at (10), fresh milk at 0	Not intense =0 Very intense = 10
Soil/muddy taste	Intensity of taste associated with soil.	Millet ugali rated at (10) Maize meal porridge at 0	Not soily = 0 Very soily = 10
Milky taste	Intensity of taste associated with fresh milk	Fresh milk rated at (10), sample CMSB rated at (6)	Not milky=0 Milky= 10
Nutty	Having the taste that is characteristic of hard roasted peanuts	Groundnuts rated at (10)	Not intense =1 Very intense = 10
Sour	Having an acid taste like that of lemon or vinegar.	20% citric acid rated at (10), cassava porridge at 0	Not sour=0
Cooked cassava flavour	Intensity of the taste associated with cooked cassava.	Cooked cassava rated at (10), fresh milk at (0)	Not intense =0 Very intense =10
Aftertaste			
Roasted soya	Intensity of an aftertaste associated with roasted soy beans	Roasted groundnuts at (10) Maize meal porridge at (0)	Not intense =0 Very intense =10
Nutty	Having an after taste that is associated with roasted a peanut that remains after swallowing.	Roasted groundnuts at (10) Maize meal porridge at (0)	Not intense =0 Very intense =10

Table 3.2 Descriptive sensory evaluation attributes definitions, references and rating scale cont…

Attributes/ descriptors	Definition	References to clarify rate the perceived sensation	Rating scale
Milky	Intensity of an after taste associated with fresh milk.	Fresh milk rated at (10) Millet porridge at 0	Not intense =0 Very intense =10
Astrigence	Chemical sensation associated with puckering of tongue caused by substances such as tannins	Whole meal bread rated at (10) Fresh milk at 0	Not intense =0 Very intense =10
Sour	Having an acid like after taste like that of lemon or vinegar.	20% citric acid solution rated at (10), cassava porridge at 0	Not sour = 0 Very sour = 10

Whole meal bread was purchased from united bakers under the trade name united® ; fresh milk from University of Eldoret dairy.

3.6.2. Consumer Acceptability

3.6.2.1. Recruitment and screening

Panelists were recruited through an advert on the notice boards of the University of Eldoret inviting interested candidates who normally consume porridge and were not allergic to soy bean. A total of 50 participants were selected to taste and rate eight samples of porridge basing on the criteria that they were adult consumers of porridge, were not part the descriptive sensory panel and could read and write. The panel comprised 32 females and 28 males whose ages ranged from 18 to 53 years. The porridge was evaluated by the panelists in five different sessions each lasting 45 minutes.

3.6.2.2. Consumer evaluation of porridge samples

The eight samples were prepared, coded and served in coded bowls of the same colour, size and shape. These were then arranged on trays that had a glass of water, carrot cubes, a pencil, serviette, and an evaluation sheet. Porridge was served when the panelists arrived which was different from the descriptive panel. The consumers were asked to rate their degree of liking for appearance, colour and texture on a nine-point hedonic scale ranging from neither like nor dislike (=5) and like extremely (=9) (Blackwell, 2006).

3.8: Data analysis

Data for proximate composition was collected in duplicate twice and analyzed using Genstat software version 16 for the mean, standard deviation and significant differences between means by Fisher's least significant difference.

Functional tests were carried out in triplicate once and the data analyzed using Genstat version 16 for means standard deviation and their means separated by Fisher's least significant difference. Descriptive sensory evaluation was done using a ten member trained sensory panel in two session of four porridge variations three different times while consumer evaluation was done once by fifty porridge consumers without any training on sensory evaluation. Descriptive and consumer sensory evaluation data was analyzed using statistica software version 6 from Microsoft cooperation. Descriptive sensory results were also analyzed for the means, standard deviation and their means separated by fisher' least significant difference, Principal Component Analysis (PCA) was also done to determine the sources of variation among the porridges. Box and whisker plots were used to illustrate consumer hedonic score distribution for the soy fortified porridge samples.

3.9. Ethical consideration

All panelists for both the descriptive and consumer acceptability evaluations signed an informed consent form before participating in the study and were free to leave at any stage if they desired.

CHAPTER FOUR

RESULTS

4.1. Proximate Analyses

4.1.2. The effect of soy fortification on proximate composition of stiff porridge (*ugali*)

Fortification with soy at 30% and 50% significantly increased the fat, ash and protein contents of *ugali* made from the plain and composite cassava flours table 4, 1. Moisture content for pure millet *ugali* was the highest at 8.5 g/100 g while cassava *ugali* was the least at 6.33 g/100 g a difference of 25.29%. For the composites *ugali* had a moisture content ranging from 6.30 g/100 g for cassava sorghum to 6.75 g/100 g for cassava millet, a 6.67% difference. At 30% fortification the moisture content increased and ranged from 9.25 g/100 g for cassava millet soy to 6.38 g/100 g for cassava soy, a 31.03% difference in the moisture contents. At 50% fortification with soy, cassava *ugali* had the least moisture content of 6.73 g/100 g while cassava-millet had the highest of 9.39 g/100 g exhibiting a 29.39% difference.

Protein content of *ugali* made from plain flours was lowest, 0.91 g/100 g for cassava and highest, 7.24 g/100 g for millet while the composites ranged from 3.68 g/100 g for cassava millet and 2.89 g/100 g for cassava-maize. Fortification with soy resulted in a substantial increase in the protein contents of the *ugali.* At 30% replacement with soy, protein content ranged from 10.24 g/100 g for cassava to 12.54 g/100 g for cassava millet soy, a difference of 18.34%. When fortified at

50%, protein content of the *ugali* was at 14.16 g per 100 g for cassava and 17.01 g/100 g for cassava-millet.

Table 4.1: The effect of compositing flours with soy meal on proximate composition of stiff porridge (*ugali*) (g/100 g dry basis)

Ugali	Moisture	Protein (N x 6.25)	Ash	Fats	CHO	Energy(kJ)[2]
100% cereal/tuber						
Cassava	6.33^{a} ±0.28	0.91^{a} ±0.11	0.17^{a} ±0.29	1.75^{a} ±0.35	90.84^{n} ±0.67	1624.40^{b}
Millet	8.5^{d} ±0.48	7.24^{f} ±0.01	0.52^{b} ±0.	4.75^{d} ±0.35	78.99^{i} ± 0.56	1641.48^{d}.
Sorghum	7.63^{ab} ±0.75	6.66^{e} ±0.47	0.25^{ab} ±0.29	2.5^{ab} ±0.35	82.96^{k} ±0.13	1616.04^{a}
Maize	8.37^{d} ±0.41	5.49^{d} ±0.31	0.25^{ab} ±0.29	3.50^{c} ±0	82.39^{j} ±0.34	1623.17^{ab}
Composite						
Cassava: Millet	6.75^{ab} ±0.25	3.68^{c} ±0.02	0.38^{ab} ±0.29	2.75^{bc} ±0.35	86.44^{l} ± 0.73	1633.73^{c}
Cassava: Sorghum	6.30^{a} ±0.25	3.51^{c} ±0.05	0.24^{ab} ±0.25	2.25^{ab} ±0.35	87.70^{m} ± 0.53	1633.77^{c}
Cassava: Maize	6.41^{ab} ±0.25	2.89^{b} ±0.01	0.25^{ab} ±0.29	2.41^{b} ±0.35	88.04^{m} ± 0.91	1634.83^{cd}
Composite (30% soy)						
Cassava: Millet	9.25^{e} ±0.29	12.54^{i} ±0.11	1.93^{c} ±0.25	6.75^{fg} ±0.35	70.33^{e} ± 0.52	1658.53^{e}
Cassava: Sorghum	7.38^{c} ±0.29	12.20^{i} ±0.05	0.88^{c} ±0.25	6.25^{ef} ±0.35	73.29^{f} ±0.07	1683.80^{h}
Cassava: Maize	6.73^{d} ±0.29	11.51^{h} ±0.05	0.88^{c} ±0.25	5.5^{de} ±0.35	75.39^{g} ± 0.41	1680.80^{e}
Cassava;	6.38^{ab} ±0.25	10.24^{g} ±0.24	0.88^{c} ±0.25	5.25^{d} ±0.35	77.26^{h} ±0.32	1681.57^{gh}
Composite (50% soy)						
Cassava: Millet	9.39^{f} ±0.25	17.01^{l} ±0.46	2.42^{e} ±0.25	8.75^{i} ±0.35	62.43^{a} ± 0.06	1674.24^{f}
Cassava: Sorghum	9.02^{d} ±0.47	16.67^{kl} ±0.29	2.13^{d} ±0.25	8.21^{hi} ±0.35	63.97^{b} ±0.32	1674.42^{fg}
Cassava: Maize	9.13^{d} ±0.48	15.26^{j} ±0.08	2.13^{d} ±0.25	7.25^{gh} ±0.35	66.23^{c} ±0.81	1653.57^{e}
Cassava	7.63^{ab} ±0.41	14.16^{j} ±0.05	2.25^{d} ±0.29	7.21^{gh} ±0.35	68.75^{d} ±0.34	1676.24^{fg}

Values are means ±standard deviation. Values in the same column with the same superscripts letters are not significantly different at $p<0.05$ as per Least Significant Difference.[1]Carbohydrate was calculated by difference {100- (% protein+ % ash +%moisture + %fat)}[2] Energy calculated by multiplication of the Atwater factors for fat (37 kJ), protein (17 kJ) and carbohydrates (17 kJ)

These showed differences at 87.43% for plain flour *ugali*, 21.47% for the composites, and 18.34% for the 30% fortified and 16.75% for the 50% fortified *ugali* variations, respectively.

The fat content was significantly different among *ugal*i made from different foods, ranging from 1.75 g/100 g in cassava, which was the least to 4.75 g/100 g for millet the highest. The cassava cereal composites had fat contents ranging from 2.25 g/ 100 g for cassava sorghum to 2.75g/100 g for millet. Fortification with soy increased the fat content significantly. At 30 % substitution the fat content of cassava *ugali* increased to 5.25 g/100 g and to 6.75 g/100 g for cassava millet while at 50% fortification 7.21 g/100 g for cassava and 8.75 g/100 g for cassava millet. The percentage difference among the stiff porridges were 63.15%, 18.18%, 2.22% and 17.6%, respectively for the plain flour *ugali* (cassava, millet, sorghum and maize), composited (CM, CS and CMi) and the fortified composites at 30% and 50% .

Mineral (ash) content of the *ugali* variations was significantly different among the plain, composited and fortified stiff porridge samples. Cassava *ugali* had the least ash content with 0.17 g/100 g, while millet *ugali* had the highest mineral content of 0.52 g/100 g, a 63.3% difference. When the cassava and cereals were composited, the ash content reduced significantly to a range from 0.25 g/ 100 g for cassava maize and 0.38 g/100 g for cassava millet resulting in a 34.21% difference. However, fortification of the plain cassava and the composited flours at both 30% and 50% resulted in increased mineral content of the *ugali*. For instance at 30% level of fortification, *ugali* contained 0.88 g/100 g of ash for cassava and 1.13 g /100 g for cassava millet, with a 22.56% difference. Additionally at the 50% level of fortification, cassava soy contained the least ash content at 2.25 g/100 g while cassava millet soy 50% had 2.42 g/100 g which was the highest at 7.55% difference.

Carbohydrate contents of plain flour *ugali* ranged from 77.3 g/ 100 g for sorghum to 90.8 g/100 g for cassava giving a 14.87% difference. Compositing of the cereals and cassava resulted in *ugali* with carbohydrate content at 89.5 g/100 g for cassava-maize as the highest and cassava millet at 86.5 as the least a 3.35% difference. Further, fortification of the *ugali* flours with soy bean led to a significant reduction in the carbohydrate contents. At 30% soy substitution, carbohydrate contents ranged from 73.9 g/100 g for cassava to 79.6 g/100 g for cassava-millet a 7% difference. Similarly at 50% the carbohydrate contents decreased further and ranged from 62.2 g/100 g for cassava-millet to 68.9 g/100 g for cassava maize a 10% differences.

Energy contents of the cassava based *ugali* variations were significantly different. On fortification, the energy contents increased to 1789.48 kJ for cassava-millet soy 30% and 1640 kJ for cassava-soy 30% an 8.35% difference while at 50% fortification from 1646.39kJ for cassava-millet 50% to 1702.92 kJ for cassava maize soy 50% a 3.31% difference.

4.1.2. The effect of soy fortification on the proximate composition of porridge (*uji*)

Results of the proximate composition of porridges are shown in table 4.2. Moisture contents of plain flour porridges ranged from 9.87 g/100 g for maize to 6.75 g/100 g for cassava a 31.6% difference while their composites ranged from 6.42 g/100 g for cassava sorghum to 5.75 g /100 g for cassava-maize a 17.39% difference. The fortified porridges

Table 4.2: Effect of fortification with soy meal on the proximate composition of thin porridge *uji* (g/100 g dry basis)

Porridge	Moisture	Protein (N x 6.25)	Fat	Ash	CHO	Energy (kj)^{2} 100 g
100% cereal/tuber						
Cassava	6.75^{d} ±0.48	1.42^{a} ±0.06	1.75^{a} ±0.35	0.2^{a} ±0.21	89.88^{k} ±0.28	1616.75^{b}
Millet	9.62^{f} ±0.48	9.08^{g} ±0.05	4.75^{d} ±035	0.53^{bc} ±0.29	76.02^{e} ±0.57	1622.40^{bc}
Sorghum	7.75^{e} ±0.48	8.32^{f} ±0.01	2.75^{bc} ±0.05	0.35^{ab}±0.24	80.82^{h} ±0.64	1617. 35^{b}
Maize	9.87^{f} ±0.25	6.98^{e} ±0.11	3.5^{c} ±0.35	0.31^{ab} ±0.08	79.45^{g} ±0.82	1598.99^{a}
Composite						
Cassava: Millet	6.12^{d} ±0.41	4.73^{d} ±0.48	2.5^{ab} ±0.35	0.26^{ab} ±0.21	86.38^{i} ±0.48	1641.46^{d}
Cassava: Sorghum	5.75^{c}.±0.48	3.66^{c} ±0.02	2.25^{ab} ±0.25	0.33^{a} ±0.24	88.01^{j} ±0.34	1641.68^{d}
Cassava: Maize	6.42^{g} ±0.25	2.78^{b} ±0.07	2.45^{ab} ±0.35	0.23^{ab}± 0.29	88.09^{j} ±0.26	1635.48^{cd}
Composite (30% soy)						
Cassava: Millet	5.62^{c} ±0.48	13.6^{k} ±0.22	7.02^{g} ±0.35	1.78^{cd} ±0.22	72.94^{d} ±0 .22	1731.60^{g}
Cassava: Sorghum	4.75^{b} ±0.41	12.52^{j} ±0.04	5.75^{ef} ±0.35	1.28^{c} ±0.23	75.89^{e} ±0.28	1715.76^{f}
Cassava: Maize	5.75^{c} ±0.35	11.82^{i} ±0.05	6.25^{fg} ±0.35	1.13^{c} ±0.11	75.31^{e} ±0.35	1712.38^{f}.
Cassava	5.60^{c} ±0.25	10.71^{h} ±0.32	5.25^{de} ±0.25	1.03^{c} ±0.05	77.54^{f} ±0.51	1694.40^{e}.
Composite (30% soy)						
Cassava: Millet	4.75^{b}±0.29	17.24^{n} ±0.46	8.75^{h} ±0.05	3.21^{f} ±0.25	66.83^{a} ±0.57	1753.06^{h}
Cassava :Sorghum	4.65^{b} ±0.35	16.59^{m} ±0.29	8.25^{h} ±0.35	2.61^{e} ±0.22	68.40^{b} ±0.38	1749.99^{h}
Cassava: Maize	4.7^{b} ±0.48	15.55^{l} ±0.16	8.55^{h} ±0.05	2.52^{e} ±0.38	69.22^{b} ±0.95	1754.08^{h}
Cassava	3.75^{a} ±0.35	15.4^{l} ±0.27	8.5^{h} ±0.25	2.53^{e} ±0.03	70.34^{c} ±0.28	1768.05^{i}

Values are means ±standard deviation. Values in the same column with the same superscripts letters are not significantly different at $p<0.05$ as per Least Significant Difference.^{1}Carbohydrate was calculated by difference {100- (%protein+ % ash +%moisture + %fat)}^{2} Energy calculated by multiplication of the Atwater factors for fat (37 kJ), protein (17 kJ) and carbohydrates (17 kJ) at 30% resulted into a substantial reduction in moisture contents ranging from 4.75 g/100 g for cassava-maize to 5.75 g/100 g for cassava-sorghum a 17.39% difference. At 50% cassava-millet was highest at 4.75 g/100 g while cassava was least at 3.75 g/100 g showing a 21.05% difference.

Crude protein content of plain cassava porridge was least at 1.42 g/100 g, while millet was highest at 9.08 g/10 g a percentage difference of 84.36%. When they were composited the crude protein contents reduced substantially and ranged between 4.73 g/100 g for cassava-millet to 2.79 g /100 g for cassava-maize at 41.01% difference. Fortification of the composite flours caused a substantial increase in the protein contents of porridges. At 30%, cassava-millet was at 13.6 g/100 g and cassava at 10.71 g/100 g showing a 21.25% difference while at 50% still cassava-millet was highest at 17.24 g /100 g and cassava least at 15.4 g/100 g a 10.67% difference.

The fat contents of individual flour porridges were significantly different. Cassava porridge had 1.75 g /100 g of fat which was the least while millet had 4.75 g/100 g of fat at a percentage difference of 63.16%. On compositing there was a substantial reduction in the fat content and they ranged from 2.5 g/100 g for cassava millet to 2.25 g/100 g for cassava sorghum, a 10% difference. However fortification led to a significant increase in the fat content of the porridges, with cassava soy 30% having 5.25 g/100 g and cassava-millet soy 30% with 7.02 g/100 g while at 50% cassava-millet soy was at 8.75 g/100 and cassava sorghum 8.25 g /100 g which showed a 5.71% difference.

Millet porridge had the highest ash (mineral) content among the plain flour porridges at 0.53 g /100 g while cassava had the least at 0.2 g/100 g, a percentage difference of 62.3%. Compositing cassava with the cereals, led to a reduction in mineral content. Among the composites, cassava-millet had the highest ash content of 0.36 g/100 g while cassava maize had the least at 0.24 g/100 g showing a difference of 33.3%. Fortification caused a substantial increase in the mineral contents both at 30% and 50%. In the porridges fortified at 30%, cassava-millet had the highest ash content of 1.7 g/100 g while cassava had the least at 1.03 g/100 g a percentage difference of 39.4%. At 50% fortification still cassava contained the least ash content of 2.53 g/100 g while cassava millet soy 50% was highest at 3.21 g/100 g giving a 21.18% difference.

Carbohydrate content of the plain flour porridges was high with cassava at 89.88 g/100 g and maize at 79.45 g/100 g giving 11.2% difference. Compositing resulted in increased carbohydrate contents of the cassava cereal composites which ranged from 88.11g/100 g for cassava maize and 86.38 g/100 g for cassava millet at a 3.68% difference. Fortification resulted in a further reduction in the carbohydrate contents of the porridges both at 30% and 50% levels. Those fortified at 30% ranged from 77.54 g/100 g for cassava to 72.94 g/ 100 g for cassava-millet showing a percentage difference of 6.14% while those fortified at 50% ranged from 69.82 g/100 g for cassava-maize to 66.83 g/100 g for cassava-millet showing a 5.13% difference.

The energy contents of all the porridges were significantly different. Among the plain flours energy content of porridge ranged from was least at 1598.99 kJ for maize while that for millet was the highest at 1622.40 kJ at 4.55% difference. The energy contents of the cassava cereal composites ranged from 1618.17kJ for cassava sorghum to 1611.11 kJ for cassava maize at a difference of 2.49 %. Addition of soy flour resulted in a substantial increase in the energy contents of the porridges both at 30% and 50% levels of fortification as their fat contents increased. At 30% substitution with soy bean the energy contents were between 1694.40 kJ for cassava and 1731.68 kJ for cassava millet at 2.02% difference while at 50% they ranged from 1768.05 kJ to 1749.05 kJ, a 2.79% difference.

4.2. Functional properties of cereal composite flours fortified with soy meal

The flour variations were evaluated for their functional characteristics and the results are presented in table 4.3. The four functional tests conducted were bulk density, water

absorption capacity, viscosity and fat/ oil absorption capacities.

Bulk densities for the plain flours ranged from 1.40 g /ml for millet to 1.46 g/ml for cassava, while their composites had ranged from 1.45 g/ml for cassava maize to 1.55 g/ml for cassava -sorghum. Fortification with soy led to a significant increase in the bulk densities of the flours. At 30% they ranged from 1.54 g/ml for cassava maize to 1.67 g/ml for cassava. Additionally at 50% fortification bulk densities ranged from 1.62 g/ml for cassava maize soy 50 a5 to 1.69 g/ml for cassava soy 50%. These showed differences in their bulk densities 2.74%, 6.45%, 7.78% and 3.55% for the plain flours, composites, 30% and 50% fortification, respectively.

The flours showed significantly different water absorption capacities. The plain flours ranged from 79.3 ml/ 100 g for cassava flour to 94.3 ml/ 100 g for millet flour while their composites ranged from 84.7 ml/100 g for cassava maize to 91.3 ml/100 g for cassava millet flour. Fortification with soy bean flour significantly increased the water absorption capacities of the flours with those at 30% ranging from 99.0 ml/100 g for cassava to 106.7 ml/100 g for cassava-millet. At 50% the ranges were 128 ml /100 g for cassava to 141.7 ml/ 100 g for cassava-millet. These were a 15.9%, difference for plain flours, 7.23% for composites , 7.22% for those fortified at 30% and 9.67% for those fortified at 50%.

Table 4.3 Effect of fortification with soy meal on the functional properties of flours and porridge

Flours	Bulk density (g/cm$^{3)}$	Water absorption (ml/100 g)	oil absorption (ml/100 g)	Viscosity (cm)
Cassava	1.46^{b}±0.55	86.3^{b} ±0.08	71.67^{a}±0.06	4.21^{de} ±0.04
Millet	1.40^{a}±0.03	94.3^{e}±0.06	92^{h} ±1.00	2.69^{a} ±0.08
Sorghum	1.43^{ab}± 0.06	92.3^{d}±0.06	85.67^{e} ±0.06	3.12^{b} ±0.12
Maize	1.45^{ab} ± 0.02	91^{c} ±1.0	83^{d} ±1.00	2.68^{a} ±0.04
Composites				
Cassava Millet	1.46^{b} ±0.01	91.3^{cd}±0.06	80.67^{c} ±1.00	3.72^{c} ±0.02
Cassava Sorghum	1.45^{ab}±0.07	85.7^{ab} ±0.06	76.67^{b} ±1.15	3.62^{c} ±0.18
Cassava Maize	1.44^{ab} 0.06	84.7^{b}±0.06	74.67^{b} ±1.01	3.23^{b} ±0.08
Soy fortified at 30%				
Cassava millet	1.58^{cd}±0.03	106.7^{i} ±0.06	95^{i} ±1.00	4.05^{d} ±0.10
Cassava sorghum	1.51^{c}± 0.03	104^{h} ±1.00	91^{h} ±1.00	4.37^{ef} ±0.11
Cassava maize	1.54^{c}± 0.07	101^{g} ±1.00	89.33^{h} ±1.00	4.25^{ef} ±0.38
Cassava s	1.67^{ef}± 0.03	99^{f} ±1.00	86.67^{ef} ±1.02	4.68^{gh} ±0.25
Soy fortified at 50%				
Cassava millet	1.69^{f} ±0.06	141.7^{m} ±0.06	98.67^{i} ±0.06	4.29^{e} ±0.26
Cassava sorghum	1.67^{ef} ±0.04	135^{l} ±1.00	94.33^{h} ±1.15	4.58^{fg} ±0.10
Cassava maize	1.62^{de} ±0.04	133^{k} ±1.00	92.67^{h}±0.06	4.41^{ef} ±0.09
Cassava	1.71^{fg}±0.06	128.7^{j} ±0.06	88.87^{g} ±0.06	4.83^{h} ±0.07

Values are means ±standard deviation. Values in the same column with the same superscripts letters are not significantly different at $p<0.05$ as per Least Significant Difference.

Viscosities of the porridges made from the un-composited flours ranged from 2.68 for maize meal to 4.21 for cassava porridge showing a 36.34% difference while the composites at 13.17% as they ranging from 3.23 for cassava maize to 3.72 for cassava millet. Fortification of the composites resulted in a reduction in the viscosities of the porridges. At 30% fortification, they ranged from 4.05 for cassava-millet to 4.68 for cassava a difference of 13.46%. At 50% soy fortification, the viscosities ranged from 4.29 for cassava-millet to 4.83 for cassava a difference of 11.18%.

Oil absorption capacities ranged from 76.67 ml /100 g for cassava flour to 92.0 ml /100 g for millet flour showing a difference of 22.1% while the composites were 7.44% as they ranged from 74.67 ml/100 g for cassava-maize to 80.67 ml/100 g for cassava-millet. The fortified flours had oil absorption capacities that ranged from 86.67 ml/100 g for cassava soy 30% to 95.0 ml/100 g for cassava-millet soy 30% showing a 8.77% difference among those fortified at 30%. For those fortified at 50% the range was from 88.8 ml/100 g for cassava soy 50% to 98.67 ml /100 g for cassava millet soy 50% a 10% difference.

4.3. Sensory evaluation

Eight porridge samples namely: cassava maize (CM), cassava millet (CMi), cassava millet soy 30% (CMiSB1), cassava millet soy 50 % (CMiSB2), Cassava, cassava soy 30% (CSB1), cassava soy 50% (CSB2), cassava maize soy 30% (CMSB1) and cassava maize soy 50% (CMSB2) were evaluated by a trained descriptive panel and a consumer panel.

4.3.1 Descriptive sensory panel

Analysis of variance of the *F*- values for the porridges profile data of the 25 attributes scored by the 10 member descriptive panel showed significant differences ($P \leq 0.05$) among the types of porridge shown in table 4.4. The data obtained were further analyzed by principal component analysis (PCA) to determine the variation and underlying relationships among the sensory attributes of the porridges resulting from the varying cereal cassava ratios and fortification with soy at 30% and 50%.

Table 4.4. Mean scores for sensory attributes of soy fortified porridges as evaluated by a trained descriptive sensory panel (n=10)

Treatments	CM	Cmi	CMSB1	CMiSB1	CSB1	CMSB2	CMiSB2	CSB2	F
Appearance									
Colour	$1.42^{a}\pm0.67$	$7.33^{g}\pm0.76$	$3.30^{c}\pm0.79$	$6.07\pm^{f}0.64$	$4.97^{de}\pm0.76$	$5.30^{e}\pm0.65$	$4.93^{f}\pm0.74$	$4.37^{c}\pm0.61$	192.72**
Specks	$1.84^{a}0.52$	$7.30^{g}\pm0.79$	$2.77^{b}\pm0.77$	$5.73^{f}\pm0.45$	$5.10^{e}\pm0.76$	$5.27^{e}\pm0.78$	$3.13^{c}\pm0.73$	$4.50^{d}\pm0.51$	209.23**
Aroma									
Roasted soybean	$0.26^{a}0.44$	$0.30^{a}\pm0.47$	$5.87^{de}\pm1.01$	$5.57^{d}\pm0.57$	$6.17^{de}\pm 0.70$	$6.70\pm^{f}0.65$	$6.33^{ef}\pm0.99$	$6.43^{ef}\pm 0.90$	413.72**
Cooked cassava	$4.84^{bc}0.78$	$6.10^{d}\pm0..96$	$3.87^{a}\pm0.97$	$4.57^{b}\pm0.77$	$4.77^{b}\pm0.77$	$5.20^{c}\pm0.71$	$3.63^{a}\pm0.49$	$3.87^{a}\pm0.63$	33.49**
Nutty	$0.39^{a}\pm0.56$	$0.47^{a}\pm0.51$	$6.10^{d}\pm0.8$	$4.90^{b}\pm0.66$	$5.50^{c}\pm0.73$	$5.10^{b}\pm0.48$	$5.50^{c}\pm0.63$	$6.13^{d}\pm0.57$	447.69**
Beany	$0.13^{a}\pm0.34$	$0.36^{a}\pm0.76$	$1.67^{bc}\pm0.66$	$1.67^{bc}\pm0.66$	$2.13^{c}\pm0.68$	$0.43^{a}\pm0.57$	$1.67^{bc}\pm0.79$	$2.13^{c}\pm0.76$	38.21**
Flavour									
Nutty	$0.19^{a}\pm0.40$	$1.01^{b}\pm0.81$	$5.50^{d}\pm 0.63$	$4.60^{c}\pm0.67$	$5.57^{d}\pm0.97$	$5.57^{d}\pm0.51$	$5.73^{d}\pm1.05$	$6.63^{e} \pm0.67$	312.30**
Milky	$1.26^{a}\pm0.86$	$3.03^{cd}\pm0.93$	$3.20^{d}\pm0.71$	$2.00^{d}\pm0.83$	$4.3^{f}\pm30.76$	$1.03^{d}\pm0.56$	$3.20^{d}\pm0.85$	$2.73^{c}\pm 0.74$	59.67**
Cooked cassava	$5.00^{c}\pm0.97$	$4.57^{bc}\pm0.63$	$5.73^{d}\pm0.74$	$3.80^{a}\pm0.71$	$4.50^{b}\pm0.51$	$5.30^{d}\pm0.75$	$3.80^{a}\pm0.48$	$4.73^{cd}\pm0.64$	30.63**
roasted soy taste	$0.23^{a}\pm0.50$	0.47b±0.51	5.97d±0.85	5.47bc±0.68	6.23d ±0.63	6.27e±0.74	5.63cd±0.72	$6.03^{d}\pm 0.81$	433.73**
Cooked Maize	$5.93^{d}\pm0.81$	$1.03^{a}\pm0.61$	$4.63^{c}\pm0.81$	$1.67^{b}\pm0.53$	$1.00\ ^{a}\pm0.59$	$4.87^{c}\pm0.63$	$0.87^{a} \pm0.51$	$1.07^{a}\pm0.69$	328.90**
Cooked millet	$0.19^{bc}\pm0.40$	$1.13^{d}\pm0.63$	$0.60^{b}\pm0.67$	$4.20^{f}\pm0.92$	$1.00^{c} \pm0.79$	$0.60\ ^{c}\pm0.56$	$3.43^{e}\pm0.73$	$0.30^{b}\pm 0.47$	156.73**
Soil taste	$0.23^{ab}\pm0.48$	$3.27^{f}\pm0.58$	$0.40^{ab}\pm 0.77$	1.67e±0.80	$0.53^{bc}\pm 0.82$	$0.67^{c}\pm0.61$	$1.00^{d} \pm0.87$	$0.23^{a}\pm0.43$	66.56**
Sour	$0.42^{ab}\pm0.62$	$0.40^{ab}\pm0.67$	$0.86^{c}\pm0.97$	$0.73^{bc}\pm0.67$	$0.60^{abc}\pm 0.77$	$0.63^{abc}\pm0.61$	$0.73^{bc}\pm0.64$	$0.33^{a}\pm0.55$	2.21**
Bland	$5.35^{d}\pm1.25$	$3.60^{c}\pm0.67$	$2.67^{a}\pm0.92$	$2.96^{ab}\pm0\ .76$	$.2.83^{a}\pm 0.75$	$3.30^{bc}\pm0.79$	$2.86^{ab}\pm 0.86$	$2.93^{ab} \pm1.11$	28.35**
Bitter	$0.45^{a}\pm0.62$	$0.53^{ab}\pm68$	$0.53^{ab}\pm0.73$	$0.33^{a}\pm 0.71$	$0.67^{abc}\pm 0.76$	$0.90^{bc}\pm0.80$	$0.53^{ab}\pm0.73$	$0.93^{c}\pm 0.91$	2.39**
Beany	$0.42^{ab}\pm0.62$	$0.23^{a}\pm0.43$	$1.93^{de}\pm0.69$	$2.13^{e}\pm0.73$	$2.33^{f}\pm 0.71$	$0.70^{b}\pm075$	$1.73^{cd}\pm0.98$	$1.53^{c}\pm0.57$	40.63**

values are means ± standard deviation .values in the same row followed by the same superscript letters are not significantly different as assed by Fischer's least significance difference test at $p<0.05$. CMi = cassava millet, CM = cassava maize, CMSB1= cassava maize soy 30%, CMiSB1= cassava millet soy 30%, CSB1= cassava soy 30%, CMSB2= Cassava maize 50%, CMiSB2 =Cassava millet soy 50% and CSB2 = Cassava soy 50%.

Table 4.4. Mean scores for sensory attributes of soy fortified porridges as evaluated by a trained descriptive sensory panel (n=10) continued

Treatments	CM	CMi	CMSB1	CMiSB1	CSB1	CMSB2	CMiSB2	CSB2	F
Texture									
Coarseness	5.42^{e}±0.85	4.13^{d}±0.97	3.43^{bc}± 0.50	3.8^{cd}±10.66	3.36^{a}± 0.61	3.33^{a}±0.88	3.53^{bc}± 0.73	3.77^{cd}±0.82	25.06**
Viscosity	6.16^{e}±0.69	4.50^{b}±0.73	3.93^{a}±0.64	4.73^{bc}±0.69	4.80^{bcd} ±0.66	4.03^{a}±0.67	5.03^{cd}±0.67	5.10^{d}± 0.71	32.03**
Aftertaste									
Roasted soy	0.23^{a}±0.43	0.46^{a}±0.82	6.03^{c}±0.76	5.50^{b}±0.63	5.97^{c}± 0.61	6.10 ^{c}±0.61	6.27^{d} ±0.74	6.10^{c}±0.55	489.73**
Nutty	0.16^{a}±0.37	0.36a±0.49	4.87^{b}± 0.86	5.50^{b}±0.63	5.13^{bc}± 0.73	5.40cd± 0.50	5.53^{d}±0 57	5.47^{d}± 0.68	419.31**
Grainy	4.52^{c}±0.51	3.63^{a}±0..76	3.57^{a}± 0.63	4.00^{b}±0.64	3.60^{a} ± 1.00	3.37^{a}±0.61	4.30 ^{bc}±0.60	3.33^{a}± 0.8	11.48**
Sour	0.45^{a}±0.72	0.50^{ab}±0.63	1.13^{d}±1.14	0.50^{ab}±0.57	0.73^{abc}± 0.78	0.87^{bcd}±0.63	1.03^{cd}±0.93	0.47^{a}±0.68	3.69**
Milky	1.87^{b}±0.81	3.90^{e}±0.88	2.70^{c}±1.09	2.23^{b}±0.86	3.53^{de}± 0.73	0.80^{a} ±0.81	3.57^{e}±0.57	3.13^{d}± 0.9	46.07**
Astringent	2.03^{ab}±1.02	2.70^{de}±0.79	1.76^{a}±0.68	2.67^{de}±0.76	2.20^{bc} ±0.66	2.50^{cde} ±0.63	2.37^{bcd}±0.56	2.80^{e} ±0.71	7.13**

values are means ± standard deviation .values in the same row followed by the same superscript letters are not significantly different as assed by Fischer's least significance difference test at $p<0.05$. CMi = cassava millet, CM = cassava maize, CMSB1= cassava maize soy 30%, CMiSB1= cassava millet soy 30%, CSB1= cassava soy 30%, CMSB2= Cassava maize 50%, CMiSB2 =Cassava millet soy 50% and CSB2 = Cassava soy 50%.

4.3.2. Principal component analyses

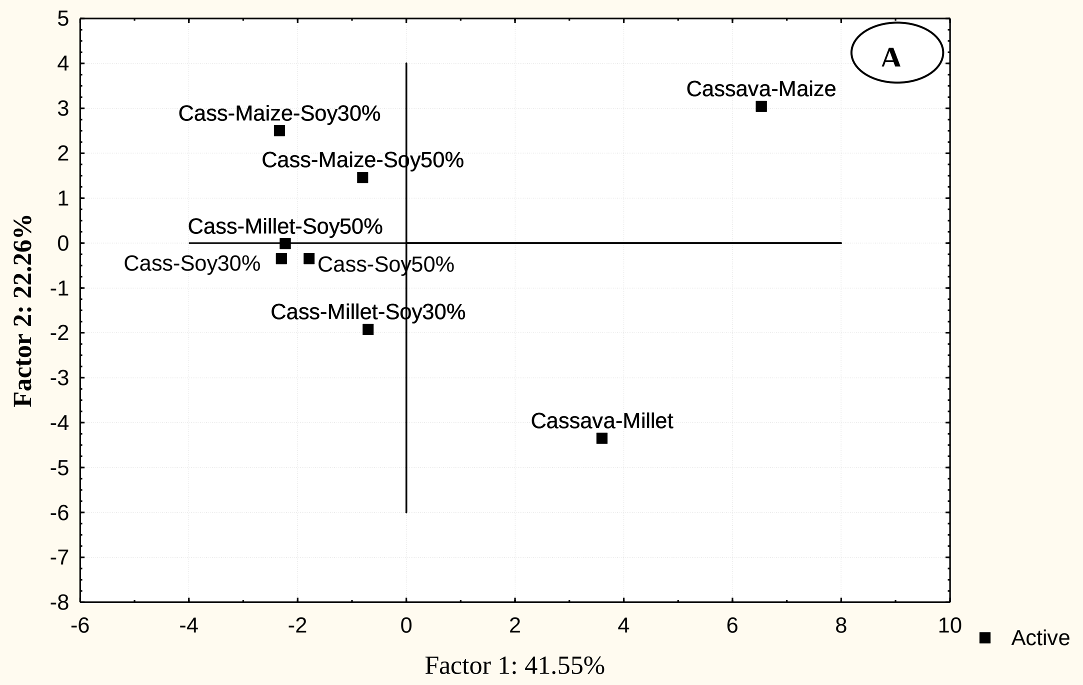
The first two principal components explained 64% of the variations among the eight porridges up (Figure 4.1). Figure 4.1a shows the first two principal component scores of porridges made from cassava based composites fortified at varying levels with soy. PC1 explained 41% of the variation based on their soy fortification with the unfortified porridges, cassava-millet and cassava-maize to the right and all the fortified variations to the left. PC2 accounted for 22% of the source of variations and separated the porridges according to colour with the lighter coloured porridges at the top and the darker coloured ones at the bottom.

The attribute loadings for the first two principal components (figure 4.1b) show the relationship between the sensory attributes of colour, texture, flavour and aftertaste. The cassava–maize porridge was associated with the attributes of cooked maize and cooked cassava flavours, bland taste and coarse and grainy texture. The cooked cassava- millet was associated with cooked cassava aroma, soil and astringent taste and dark colour. The soy fortified porridges were associated with roasted soy taste and flavour, nutty aroma and flavour and beany flavour.

The third principal component was used to further explain the variations as the first two had only explained 64%. Figure 4.2 shows the first and third principal components. Figure 4.2a shows that factor 1 and 3 explained 55% of the variation. PC3 explained 14% of the variation and separated the porridges according to the taste with the bitter and astringent tastes at the bottom and beany tastes at the top. Bitter tastes were associated with porridges containing millet and the beany ones with those containing soy.

Since principal components 1and 2 explained more than 75% source of variation in the porridges based on factors 1, 2 and 3, there rest of the factors then only explained

25% we found it not necessary to go for the 3rd principal component.



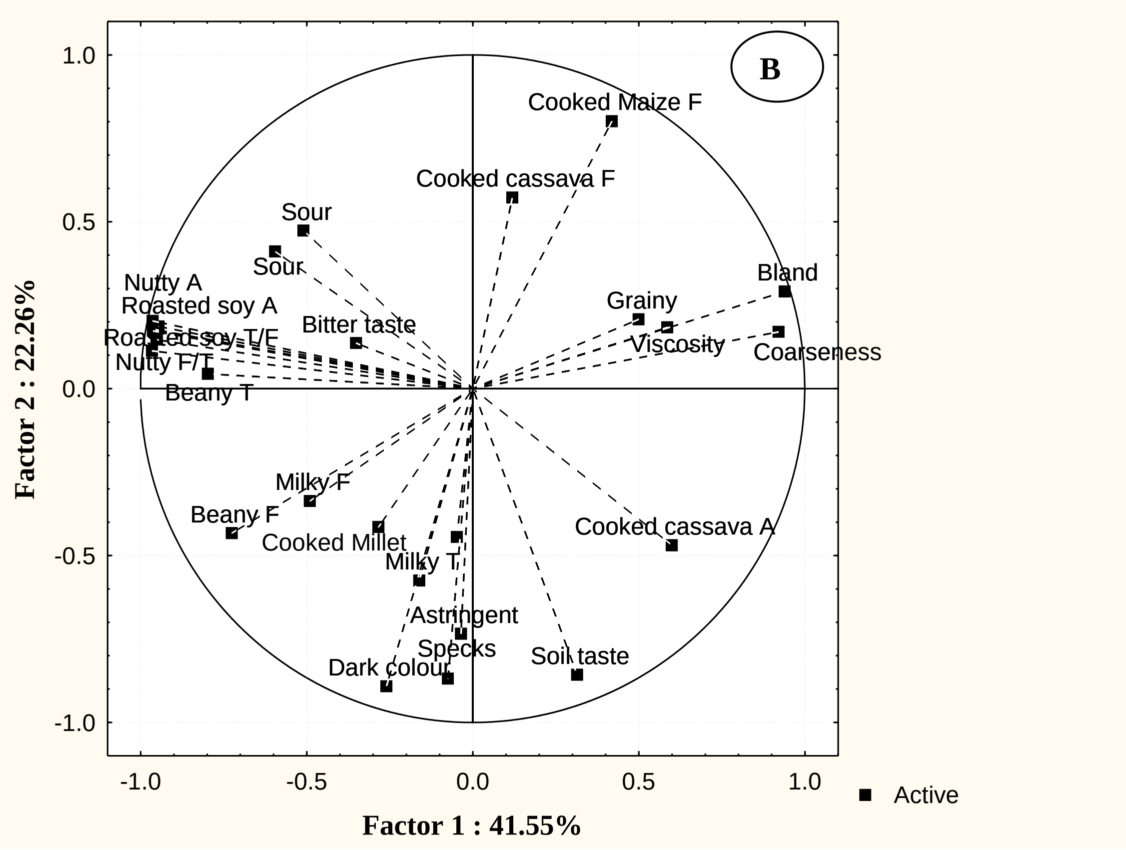


Fig 4.1 A and B: Principal Component Analysis of the porridges (A) Plot of the first two principal component scores of the porridges (B) Plot of the first two principal component loading projections of the sensory attributes

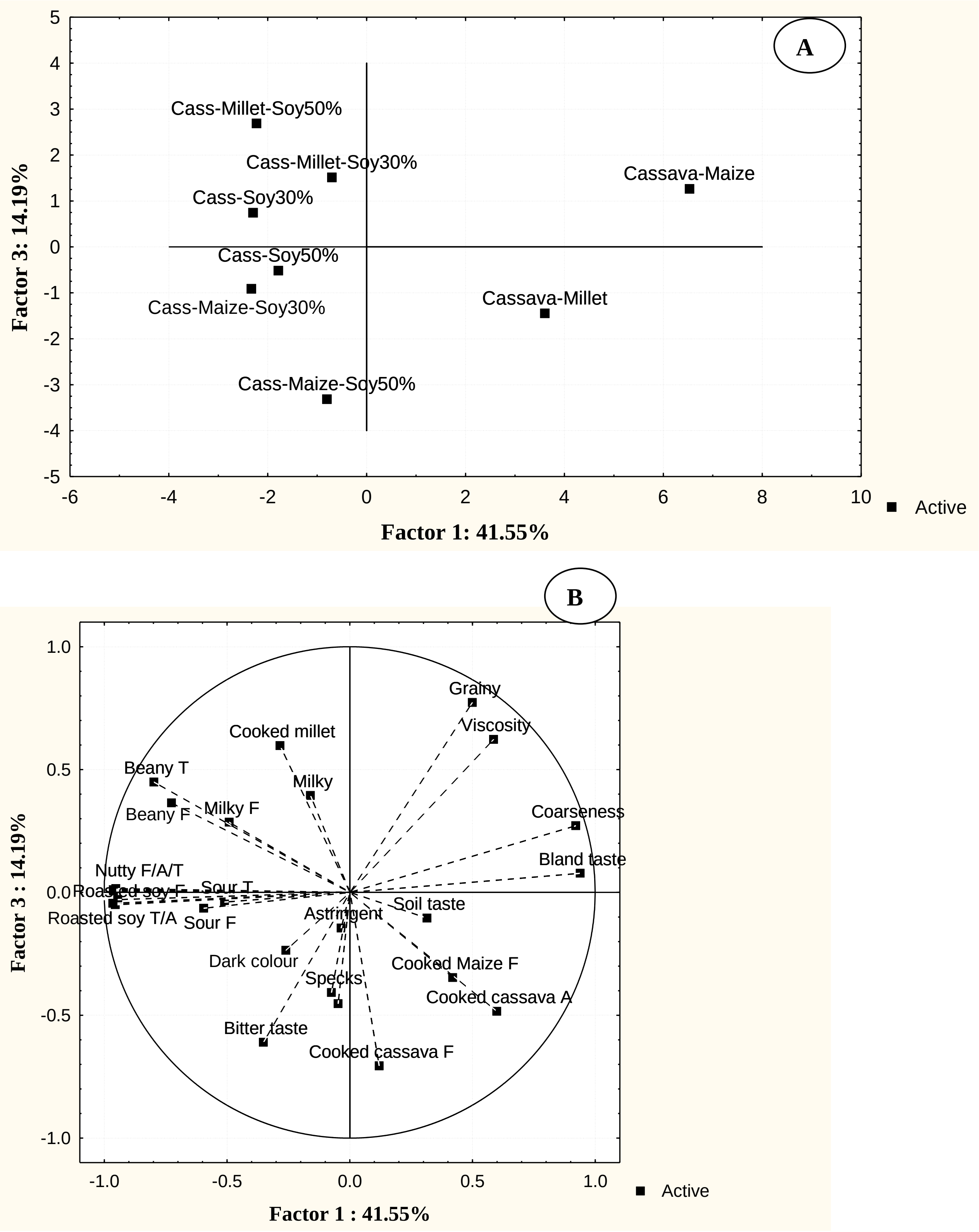


Fig 4.2A&B: Principal Component Analysis of the porridges (A) Plot of the first and third principal component scores of the porridges (B) Plot of the first and third principal component loading projections of the sensory attributes.

4.3.3. Consumer evaluation

A total of 50 adults evaluated the eight porridge samples and rated them on a scale depending on their liking for the coluor, taste and texture. The results were as presented in a spider plot in figure 4.3. The colour, taste and texture were significantly different among the eight porridge samples. Cassava millet porridge was most liked by the panelists for the coluor, texture and taste therefore was most acceptable followed by cassava millet soy 50% CMiSB2 while Cassava Maize was least liked for all the three attributes that were ranked by the consumer panelists.

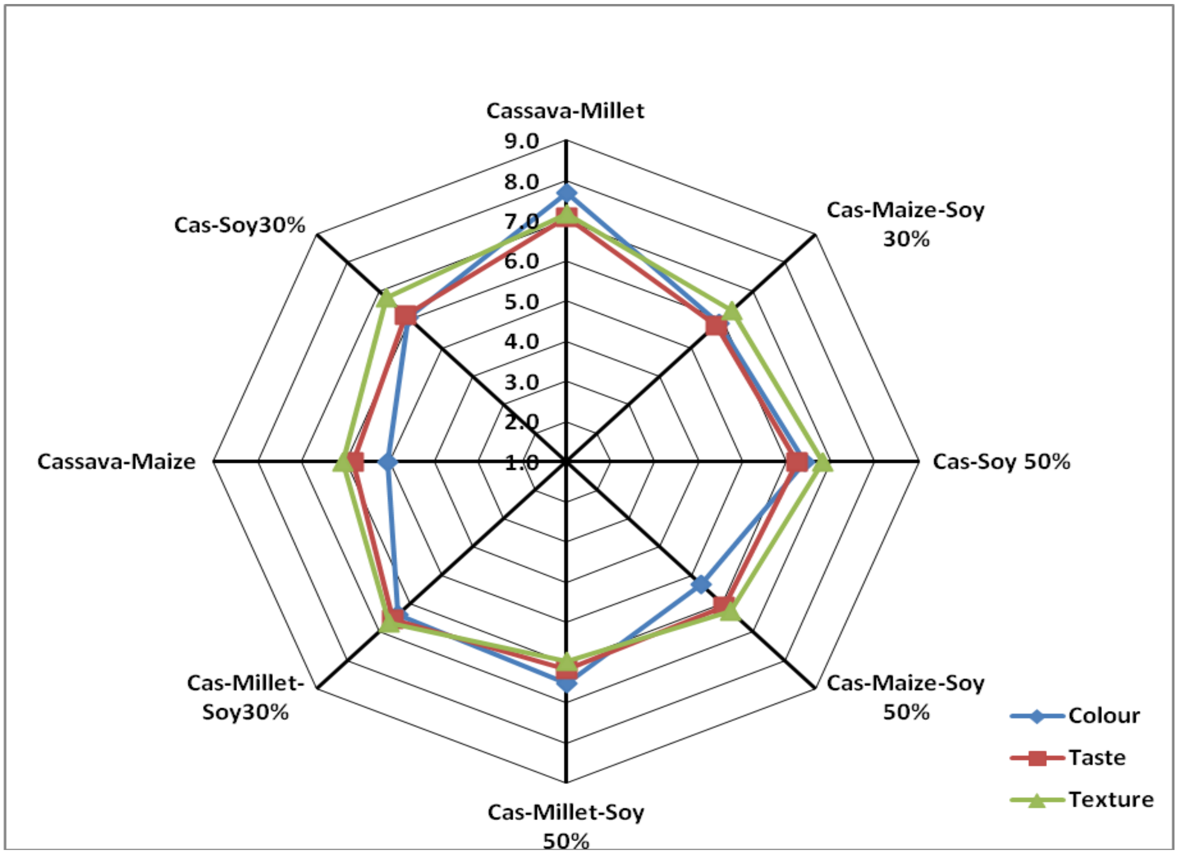


Figure 4.3: The effect of fortifying with soy meal on consumer perception of porridge sensory attributes**.**

4.3.4. Total quality

The means for the total quality as were evaluated by the consumer panelists were significantly different as in the figure 4.4. Cassava millet porridge scored the highest overall this was liked best for its colour, texture and taste giving it a mean of 7.32. Cassava millet soy 30% followed after cassava millet with a mean of 6.54, then cassava soy 50% with a mean of 6.46.

On the other hand cassava maize was liked least for its colour, taste and texture scoring 5.63 followed by cassava maize soy 30% at 5.83, then cassava maize soy 50% at 5.92. Generally millet based porridge were more liked therefore scored higher than the rest while the maize based ones were least liked therefore score low. This means showed a percentage difference of 23.08 between cassava millet (7.32) and cassava maize (5.63)

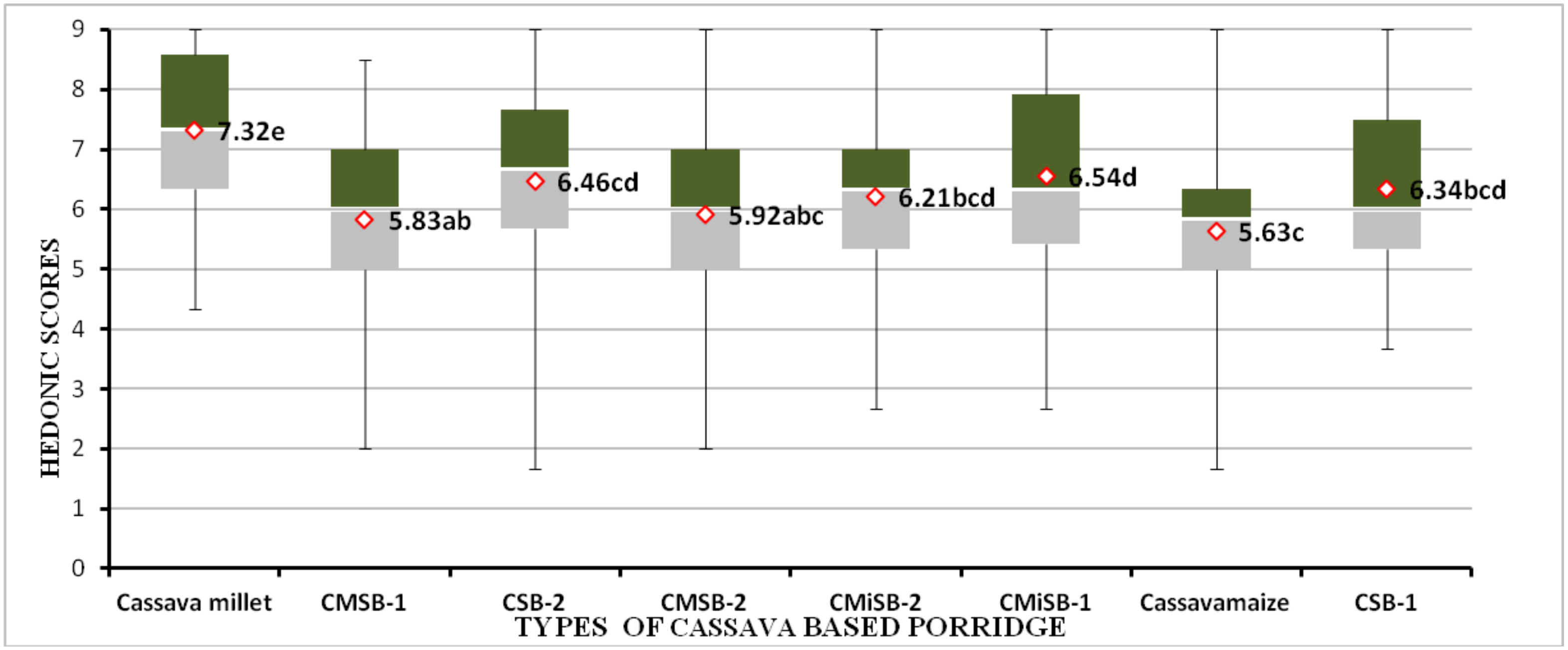


Fig.4.4. The effect of fortifying composite flours with soy meal on the total quality of porridges
The means were separated using L.S.D and those with different letters are significant at $p< 0.05$.). The upper percentile is the dark shaded area represents where 75% of the values fell, the bottom represents the value below the median mark that were 25% and below while in between is the median where 50% of the values fell above and 50% below. Hedonic rating scale, 1=dislike extremely, 5= neither like nor dislike, 9= like extremely. CMi = cassava millet, CM = cassava maize, CMSB1= cassava maize soy 30%, CMiSB1= cassava millet soy 30%, CSB1= cassava soy 30%, CMSB2= Cassava maize 50%, CMiSB2 =Cassava millet soy 50% and CSB2 = Cassava soy 50%.

.

CHAPTER FIVE

DISCUSSION

5.1 Proximate Analyses

5.1.1. Proximate composition for stiff porridges

The moisture content among ugali variations made from cassava based composite flours was significantly different. This may have been influenced by the extent of drying during processing prior to evaluation. Moisture content of a food is a determinant of the foods storage stability as foods with high moisture content spoil faster than those with lower moisture content (Fathelrahaman & Kheri, 2015). However, this is not applicable to ugali as it is prepared and consumed immediately therefore does not require storage.

Cassava ugali had the lowest protein content 0.91 g/100 g compared to all the cereals, millet was more than six times higher in protein content than cassava *ugali*. These results are in agreement with USDA (2015) on protein content of these foods. Compositing cassava with millet, sorghum and maize flours resulted in substantial increase in the protein contents of the ugali variations by about 3 times, an indication that compositing cassava with other cereals is a means of improving protein content. This may be attributed to the higher protein content of the cereal flours (USDA, 2015). Fortification of the composite flours with soy meal caused a dramatic increase in protein content of all ugali variations. Replacement with 30% soy flour resulted in increase of a 12 times for pure cassava-soy and 14 times at 50% soy fortification. This may be explained by the higher protein content of between 35 and 40% in soy meal compared to the cereals (Serrem *et al*, 2011) and tuber. A similar study by (Mutambuka, 2013), also reported soy protein content more than twice that of any cereal. Proteins are essential for growth, repair and maintenance of the body therefore promote normal functioning (Gropper *et al,* 2009).

Ash contents of ugali variations made from plain flours were also significantly different with cassava again having the least while millet 67.3% was highest. This is an indication of differences in the mineral contents of the cereals and tubers (USDA, 2015). Addition of soy meal to cassava flour and its cereal based composites resulted in significant increase of ash. At 30% and 50% soy replacement in cassava ugali, the mineral contents increased three and six times, respectively while its composites , cassava millet had a 13 times increase in ash content at 50% soy replacement. This increase in the ash content of the ugali probably was caused by the soy meal that has much higher mineral content than of cereals and tubers (Smolin & Grosvenor, 2010). A study by Balogun *et al*, (2012) reported 11.35% increase in the ash content of tapioca meal when fortified with soy at 20% while Anuonye (2011) reported a 75% increase at 25% soy substitution of millet flour.

Fat content was lowest in cassava ugali but millet among the cereals in this study was 171% higher than cassava. Compositing significantly increased the fat content by 57% and 37% in cassava-millet and cassava-maize variations, respectively. This was probably due to the cereals substantially higher fat content compared to cassava flour (USDA, 2015). Fortification with soy at 30% further increased the fat content by 145% in cassava-millet and 200% cassava-soy while at 50% fortification the increase was 218% for cassava-millet and cassava-soy by 312%. Increased fat content possibly resulted from the high fat of about 18% in soy beans (Adenekan, 2013). Soy beans store more energy in the form of fat than cereals and tubers (Madukwe, Edeh & Obizoba, 2013) which were the likely cause of an increase in fat content on fortification of the cassava based composites. The findings in this study are similar to those by Bunereka and Mahendran (2009) who also reported an increase in the fat contents of wheat biscuits on addition of soy by 35% at 25% soy fortification. Another study by Ugwuona (2009) also found similar results on soy fortification at 20% realizing a 31.7% increase in the fat content of cassava wheat biscuits. Fat is a concentrated source of energy for humans, and plant sourced fats in the diet are healthy and because they promote heart health (Smolin & Grosvenor, 2010).

Cassava ugali had the highest carbohydrate content while millet the least by 13%. This may be explained by the fact that tubers store almost all their energy as carbohydrates (Ugwu, 2009). Fortification of cassava flour with soy meal at 30% and 50% caused a 15% and 24% reduction, respectively in the carbohydrate contents of the ugali variations. This may be attributed to legumes storing less energy in the form of carbohydrates (Madukwe *et al*, 2013). Other researchers have also reported similar results. Opeifa *et al* (2014) found a 7.1% reduction in the carbohydrate content of maize meal *ogi* at 15% replacement with horse eye bean flour while Serrem *et al* (2011) reported 28.2% reduction on soy substitution at 50% in sorghum biscuits. Carbohydrates are an important source of energy and spare protein for the most important body functions rather than energy provision (Rao, 2009).

Fortification of cassava at 50% with soy bean caused a 3.3% increase in its energy content. This may be due to soy bean having more fat in the form of energy hence a higher caloric value (USDA, 2015). A study by Kouakou *et al* (2013) showed that fortification of millet flour with soy beans at 30% increased its energy content by 31.5%. Madukwe *et a*l (2013) also reported a 9.6% increase in the energy content of wheat cookies on fortification of wheat flour at 10% with bambara groundnut flour. At 30% soy replacement in plain cassava ugali, it provides 28.9% of the daily energy requirement for a five year old girl. High energy content in the diet indicates that the body will obtain enough calories from it (fat and carbohydrates) therefore spare proteins for growth, repair and maintenance (Stipanuk, 2006).

5.1.2. Proximate composition of porridge

Proximate composition of cassava and cassava cereal composites followed the same trend as that of ugali. For instance cassava had significant levels of increase in the protein contents at 74% after composition with millet which could be due to the high protein content in millet (Anuonye, 2011). Soy replacement in the cassava cereal again caused substantial increase in the protein contents at both 30% and 50% by 87% and 90.78% respectively. However, the values for in all variations were higher than those of ugali by 36%, 18%, for protein and ash respectively while 1.1% and 47% lower for carbohydrates and energy respectively. This may be explained by the maillard reaction enhanced by high temperature, less moisture and the longer cooking time required to make ugali have an appetizing aroma and flavour. According to Blackwell (2006), high temperature, low moisture and long time cooking increase the rate of the maillard reaction which is non-enzymatic chemical reaction between an amino acid and a reducing sugar that forms chain reactive intermediaries leading to the formation of flavour and melanoidin compounds therefore lowering the protein quality. For instance cassava ugali had 0.91% protein while porridge had 1.42% a trend similar to that of the ugali and porridge that was made from the composited flours.

5.2. Functional characteristics

5.2.1. Bulk density

The bulk density of cassava flour was different from that of millet by 41% which could have been due to the husks of the millet grain which was milled whole making it to compact less (Fathelrahaman & Kheri, 2015). Fortification increased the bulk densities of cassava by 14.4% at 30% soy replacement and 17.2% at 50%. This could have been due to the low fibre content of soy bean that enhanced the compacting together of the flours (USDA, 2015). A study by Opeifa *et al* (2015) reported that addition of legume (horse eye bean) flour into maize increased its bulk density by 15%, similar to soy bean in the current study. Bulk density of flour determines how the flour can be compacted therefore flours with high bulk densities can be packed in a smaller space and less material is used for packaging (Taiwo *et al,* 2010). Also high bulk density means a lot of nutrients in a small volume (Fathelrahaman &Kheri, 2015). Soy fortified flours were been found to pack together better than the unfortified ones therefore preferred for supplementary feeding (Akubor &Ukwuru, 2003). According to Muoki (2015), flour with high bulk density also indicates that its porridge will provide more nutrients to consumers since more nutrients are packed together than flour with low bulk density.

5.2.2. Water absorption capacity

Water absorption capacity was different among the plain flours of cassava, maize, sorghum and millet. This may be because of the difference in the protein contents of the flours (USDA, 2015) and conformation (Mutambuka *et al*, 2013). On soy fortification the water absorption capacities of the cassava increased by 14.7% and 49.1% at 30% and 50% soy replacement in the cassava flours respectively. This increase could have been caused by addition of soy flour into the cassava flour. Soy bean has higher protein than the tubers and cereal which is of good quality (Martin *et al,* 2010) and could have increased the water absorption capacities of the flours. According to Oyetoro *et al* (2013), water absorption or holding capacity in a food is based on protein content, basically on the amino acid composition, protein conformation and surface polarity. According to

Mutambuka (2013) water holding capacity of 3.18 g/g and 2.77 g/g for albumins and globulins, respectively while oil holding capacity was 3.29 g/g and 3.23 g/g, respectively. Therefore including beans into a cereal or tuber flour is expected to increase its water and oil absorption capacities significantly. It is possible that the water absorption of the fortified flours was increased by addition of soy flour which has high protein content and quality because the albumins and globulins of beans are soluble in water (Mutambuka 2013). In contrast, cereal proteins are albumins, prolamins, globulins and glutelins, of which only albumins are soluble in plain water (Koehler & Wieser, 2013). A study by Kouakou et al, 2013 also showed that addition of soy bean into millet flour increased its water absorption capacity by 30.8%. Another study by Akubor and Ukwuru, (2003) demonstrated that addition of soy flour into tuber flour significantly increased its water absorption capacity by 28.3%.

5.3.3. Fat/ oil absorption capacity

Plain flours had significantly different oil absorption capacities possibly due to the difference in their protein content (USDA, 2015). A study by Chandra and Samsher (2013) showed that different cereals have varied oil absorption capacities as well as tubers which were similar to the findings of this study. Compositing cassava and millet flours increased the oil absorption capacity of cassava millet by 12.6%. This may have been caused by the higher protein content of millet (Bwai *et al*, 2014). Soy flour replacement in the cassava further increased the oil absorption capacities of cassava flour by 20.9% and 24% at 30% and 50%, respectively. Oil absorption capacity of flour is related to the amino acid profile of flour determined by the ability of proteins to swell and unfold exposing additional binding sites, thus increasing the potential for interaction with other compounds as well as digestibility (Essuman, 2014). Fat absorption capacity correlates positively with good flavour and taste, therefore determines the use of flour in bakery (Jideani, 2011). Fat absorption also improves the texture of a food product made from the flour and therefore positively influences its acceptability. Another study by Akubor and Ukwuru (2003) reported an increase in the oil absorption capacity of flours on addition of soy bean, which concurs with findings of the current study. The increased oil absorption capacity on addition of soy bean into cassava based composites could have been due to the increase in protein content of the flours. According to Chandra and Samsher (2013), the ability of flour to bind oil makes it useful in foods where optimum oil absorption is needed. It makes flour useful in facilitating flavour and mouth feel enhancement for example in whipped topping, sausages, chiffon desserts and sponge cakes.

5.2.3. Viscosity

Viscosity of cassava porridge was different from maize meal porridge by 36.3%. Soy fortification of cassava of cassava flour at 30 % and 50% reduced the viscosity of their porridges by 11.2% and 14.7% respectively. Viscosity of the porridges reduced significantly on addition of more soy bean into the composites, this could have been caused by the water soluble albumins and globulins in soy (Koehler &

Weiser, 2013) which absorbed more water and thus reducing the viscosities of the porridges. Viscosity of a food is a measure of the intrinsic ability of a fluid to resist flow under force and is quantified as the ratio of shear stress (transmitted by the fluid) to shear rate (transmitted by material deformation) (Kim, 2007). It is a key determinant of its acceptability as it influences chewability and ease of swallowing (Fathelrahaman, Kheri & Ahamed, 2015). Very thick and sticky porridges are not easily swallowed by children and Dysphagia patients (Masters et al, 2013). Kin, Yoo &Yoo (2014) investigated the relationship between apparent viscosity as measured by a viscometer and the line spread test, they concluded an inverse relationship between the two measurements.

5.3. Sensory evaluation

5.3.1. Descriptive sensory evaluation

Figure 4.1 explained variation in the porridges based on Principal components 1 and 2. In Factor 1, 41.5% of the variation was due to fortification with soy. This in Figure 4b was associated the fortified porridges with soy bean related sensory descriptors such as nutty, roasted soy, beany aromas and flavours as well as after taste. According to Ari *et al* (2012), soy beans contain various anti nutritional factors which negatively affect its nutrient bioavailability as well as lowers acceptability. In order to counter this, thermal processing has been reported to reduce ant-nutrients and increase acceptability by generating of desirable flavours and aromas from the interactions between amino acids and reducing sugars

(Blackwell, 2006). The difference in the intensity of the nutty, roasted soy and beany flavours, aromas and after taste among the samples is likely to be due to the addition of roasted soy bean flour into the cassava based cereal flour. Beany flavour and aromas could be due to the presence of volatile carbonyl compounds including aldehydes, ketones and alcohols (Odu, Egbo &Okwonko, 2012) in the soy fortified porridge variations.

Principal component 2 explained variation among the porridges based on the appearance, basically the intensity of colour from lighter to darker at 22.26 %. Millet based variations were the darkest while the maize based ones were lighter in colour. The dark colour contributed by the presence of millet might have been caused by condensed tannins in form of proanthocyanidins naturally occurring in millet concentrated in the seed coat responsible for its dark colour making it darker in colour than other cereals (Taylor *et al*, 2013).

Principal component 3 showed that 14.2% of the variation was based on the texture of the porridges especially coarseness and graininess that was associated with cassava maize porridge. Whole milled maize flour has coarse particles (Nkhabutlane, Rand & De Kock, 2014) that may have caused coarseness and graininess in the maize flour porridge.

The panelists identified both astringency and bitterness in varying intensities in all the samples. According to Taylor et al (2013), all cereals contain phenolic acid concentrated in the endosperm and bran. These mainly occur in form of condensed tannin (proanthocyanidins) concentrated in many parts of the grain for example in the seed coat of millet. Tannins are known to impart the dry and puckering sensation of astringency in the oral cavity which seems to involve binding of tannins to the Proline rich proteins. They are therefore responsible for astrigence and bitter sensations in the oral cavity. This could be because the cereals (millet and maize) were milled whole therefore could have contained different levels of tannins depending on the content per cereal.

The panelists also identified the cooked maize flavour and aroma especially in the cassava maize and its fortified porridges which were rated high. Cooked maize flavour and aroma is probably the popcorn aroma caused by 6-acetylehydropyridine, 2-acyl-1-pyroline (2AP) and its analogues present in the maize grain (Taylor et al, 2013). Nkhabutlane et al, (2014) reported cooked maize flavour and taste in the maize based breads and associated them with the maize prolamins.

5.3.2. Consumer acceptability

Consumer panelists preferred dark colored porridges and ranked them higher than the light coloured ones. Cassava millet for instance was the darkest among the porridges and was liked best followed by the other millet based porridges which were soy fortified. Darker coloured porridges were preferred to lighter porridges since most people are familiar with those made traditionally for millet and sorghum grains (Muoki et al, 2015). According to Taylor et al (2013), the tiny finger millet grains have a dark coloured seed coat richer in polyphenol compounds compared to other grains like barley, rice, maize and wheat. Higher concentrations are found in the aleurone layer, testa and pericarp. These polyphenolic compounds especially tannins in the seed coat inhibit microorganisms invasion. The panelists liked the millet based samples by rating them high for coluor and texture. This could have been due to the darker colour and the texture that they were familiar with therefore the samples were more liked than the lighter coloured ones.

5.4. General discussion

Viscosity of porridges variation was evaluated by the line spread method of Mc Williams (2011) which was able to differentiate the porridges basing on their thickness which gave good result that are comparable to those of a viscometer as it has been reported in similar studies , however the line spread test is time consuming and require patience and technical skills.

Descriptive sensory tests results had a lot of variations especially for aroma and flavour which could have been partly caused by the differences in the perception of the attributes by panelist. Additionally we could not totally control what the panelists eat prior to the sessions which could cause variation in the ability to rank the intensity of the attributes and one of the panelists fell sick and had to take medication which could influence their sensory acuity.

Generally the proximate, functional and sensory tests showed that millet based ugali and porridge were superior to the rest of the variations. This indicates that millet plain or composited with cassava when soy fortified and prepared into ugali and porridge or flours have the best quality characteristics therefore can be adopted and utilized as nutrient dense foods for Western Kenya households' children and adults or any other population inform of supplementary feeding.

However since millet is not grown widely in as cassava and soy are, cassava can still be fortified with soy bean as a sustainable strategy to alleviate PEM as they are locally available (FAO/WHO, 1994). Cassava soy 30% ugali and porridge provides 50% of the daily protein requirements of children 1-3 years in 100 g, its functional characteristics: water and oil absorption capacity, viscosity as well as bulk density of this flour were good. As demonstrated in table 5.1, the cost of the soy fortified flours is slightly higher than the unfortified since soy bean is expensive but based on the improved nutritional value it is worth it. Additionally as reported in literature, soy is widely cultivated in Western Kenya by most of the household as a cash crop. However its consumption is low this therefore will help them consume it in diets which are even cheaper because they do not need to purchase.

Flour variations	Description	Cost per 1kg Ksh.
Cassava maize	Cassava 600 g @ 30; maize 400 g @16	46
Cassava millet	Cassava 600 g @ 30; millet 400 g @43	63
Cassava soy 30%	Cassava 700 g @35; soy 300 g @ 18	53
Cassava soy 50%	Cassava 500 g @25; soy 500 g @ 35	60
Cassava millet soy 30%	Cassava 460 g @23; millet 240 g @ 24;soy 300 g @18	65
Cassava millet soy 50%	Cassava 300 g @15 ; millet 200 g @ 21; soy 500 g @30	66
Cassava maize soy 30%	Cassava 460 g @23; maize 240 g @ 12; soy 300g @18	53
Cassava maize soy 50%	Cassava 300 g @ 18;maize 200 g @ 9; soy 500 g @30	56

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

6.1. Conclusions

1. Fortification of cassava flour with 30% and 50% soy dramatically improves the protein content of thick and thin porridges. The products which can provide more than 50% of the daily protein requirements of 1-3 year children in 100 g have the potential to alleviate Protein Energy Malnutrition.
2. Soy fortified thin porridge has higher protein content than thick porridge.
3. Soy Substitution of cassava and cassava: cereal composite flours 30 and 50% significantly improve their water and oil absorption capacities, bulk density and viscosity.
4. Porridge made from millet and cassava composite flours fortified with soy at 30 and 50% are the best liked by consumers.

6.2. Recommendations

1. Households and processors should fortify single cereals and tubers with soy bean as these results in the best nutrient density in the products than when composites are fortified.
2. Cassava, maize, millet and sorghum should be fortified with soy meal to get porridges that can provide up to 17% protein in 100 g.

6.3. Recommendations for further research

- More studies can be done on digestibility of the proteins in the soy fortified cassava cereal porridges and their effect on growth of experimental animals

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APPENDICES

APPENDIX I: Panelist Invitation Poster

Do you take porridge?

We need to train 13 people from 12th to 23th May 2014, Mondays to Fridays 10:00 to 11:00 for evaluation of porridge made of Cassava, Millet, Maize, and Soy flours. Previous taste panel experience will be an added advantage.

If you are interested please contact Everlyne at the project office next to Food lab, opposite student's centre on Wednesday 7th

Call or text on 0714995116 to register your interest

APPENDIX II: Panelist's Consent Form

Sensory Evaluation of Fortified Porridge

Thank you for your willingness to potentially participate in a sensory evaluation project at the Department of Family and consumer sciences, University of Eldoret

Voluntary Nature of Participation: I understand that participation in this project is completely voluntary. I do not have to participate in this sensory project. If I do not agree to participate I can withdraw my participation at any time.

Risks to the individual: I understand that I will evaluate soy fortified maize, millet and cassava porridges using descriptive sensory evaluation. The risk involved in taking porridge samples is no greater than that of taking any other at home or any food service establishment. I note that people who are allergic to soy should avoid these products.

Confidentiality: participants are not required to reveal any confidential information. All responses to questions will be treated in a confidential manner. Responses to sensory questions via the evaluation form are tracked using numbers only. These numbers are not in any way related to the participant's name.

If you have any questions about this sensory project, contact Everlyne Sikuku, Department of Family and consumer sciences, University of Eldoret at project office or 0714995116

I HAD THE OPPORTUNITY TO READ THIS CONSENT FORM, ASKED QUESTIONS ABOUT THE SENSORY PROJECT AND I AM PREPARED TO PARTICIPATE IN THIS PROJECT.

Participant's Signature Date

Participant's Name (*please print clearly)*

Sensory Panel Leader Signature Date

APPENDIX III: Descriptive Sensory evaluation ballot

WELCOME TO THIS TESTING SESSION

DEPARTMENT OF FAMILY AND CONSUMER SCIENCES

UNIVERSITY OF ELDORET

PANELIST CODE …………..

PANELIST NAME …………………………………………

ENTER TRY NO. …………………………………………..

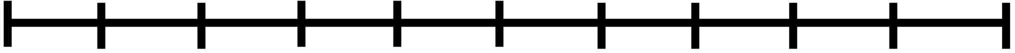
Instructions

You are provided with four (4) samples of porridge. Please taste the samples in the order presented from left to right. Take a sip of water and eat a piece of carrot before you start tasting and in between tasting the different samples. Circle the relevant bar on the scale provided for each attribute.

Question 1:

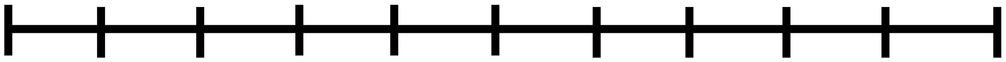
Look at the sample …………………………. and rate the following appearance descriptors

Not dark Intensity of darkness **Very dark**



Presence of specks

A few specks **Many**



Question 2:
Smell sample ………using short sniffs and rate the intensity of the following aroma descriptors

Roasted soy bean aroma

No aroma | Intense **aroma**

Cooked cassava aroma

No cassava aroma | Intense cassavaaroma

Nutty aroma

No nutty aroma | **Intense nutty roma**

Beany aroma

No beany | **Intense beany aroma**

Question 3:
Taste sample ………………and rate the intensity of the following taste descriptors

Nutty taste

No nutty taste | **Intense nutty taste**

milky taste

No milky taste | **Intense milky taste**

Cooked sorghum taste

No cooked sorghum taste | **Intense sorghum taste**

Cooked cassava taste

No cooked cassava **Intense cooked cassava**

roasted soya taste

No roasted soy **Intense roasted soya**

Cooked maize taste

No cooked maize taste **Intense cooked maize**

Cooked millet taste

No millet taste **Intense cooked millet**

soil taste

No soil taste **Intense soil taste**

No sour taste **Intense sour taste**

bland taste

No bland taste **Intense bland taste**

Bitter taste

No bitter taste **Intense bitter taste**

Beany taste

No beany taste **Intense beany taste**

Question 4:
Taste sample …………….and rate the intensity of the following texture descriptors

Coarseness

Not coarse **Extremely coarse**

viscosity

Not viscous **Viscous**

Question 5:

After swallowing the soybeans, rate the after taste of the sample …………………………..

roasted soya

No roasted soya after taste **Intense soya after taste**

nutty after taste

No nutty after taste **Intense nutty aftertaste**

Grainy residue in the mouth

Not grainy **Very grainy**

sour after taste

No sour after taste **Intense sour after taste**

milky after taste

No milky after taste **Intense milky after taste**

astrigence

Not astringent **Extremely astringent**

Any other Comments:

………………………………………………………………………………………

………………………………………………………………………………………

APPENDIX IV: Consumer Panel Evaluation Sheet

You are provided with 8 samples of porridge to evaluate and rate their colour, taste and texture as per the scale provided. Tick (√) in the appropriate box according to your liking

Porridges codes												
	Colour	taste	texture	colour	taste	texture	colour	Taste	texture	Colour	Taste	texture
Dislike Extremely												
Dislike moderately												
Dislike slightly												
Dislike												
Neither like nor dislike												
Like												
Like slightly												
Like moderately												
Like extremely												