NUTRIENT COMPOSITION, EFFICACY, AND CONSUMER ACCEPTABILITY OF SOY FORTIFIED COMPLEMENTARY FOODS FROM WESTERN KENYA

BY

KAMAU ELIJAH HEKA

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THEREQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN COMMUNITY NUTRITION OF THE UNIVERSITY OF ELDORET, KENYA

2015

DECLARATION

DECLARATION BY THE CANDIDATE

I declare that this thesis is my original work and has not been presented for a degree in any other university or institution of higher learning. No part of this thesis may be reproduced without prior consent of the author and/or University of Eldoret, Kenya

……………………. …………………….

KAMAU ELIJAH HEKA **DATE**
AGR/PGF/002/12

DECLARATION BY SUPERVISORS:

This thesis has been submitted for examination with our approval as the university supervisors.

…………………………. ………………………….

DR. CHARLOTTE A. SERREM **DATE**
Department of Family and Consumer Sciences,
School of Agriculture and Biotechnology,
University of Eldoret.

…………………………. ………………………….

DR. FLORENCE W. WAMUNGA **DATE**
Department of Family and Consumer Sciences,
School of Agriculture and Biotechnology,
University of Eldoret.

DEDICATION

This thesis is dedicated to:

My loving dad and mum, Mr. and Mrs. Joseph and Rebecca Kamau for their selfless sacrifice towards giving me a strong foundation in life through education. I am very proud of you and appreciate the sacrifices that you made.

My dear wife Carolyne Heka and my lovely daughter Kelsey Leona Heka; you are my pillars in life; you give me a reason and inspiration to be the best I can. I appreciate your unending and unconditional support.

I love you all.

ABSTRACT

Protein Energy Malnutrition accounts for half of the annual deaths of children aged below five years. Complementary foods for such young children should be protein rich and nutrient dense. Compositing complementary flours with legumes of high protein quality such as soy can be effective in abating malnutrition. The objective of this study was to develop soy-fortified complementary flours using locally available foods from Western Kenya and to determine the effect soy fortification on proximate composition, protein nutritional quality, growth, rehabilitation, and consumer acceptability**.** Two exploratory focus group discussions were carried out to establish how complementary foods are prepared in Western Kenya. To determine proximate composition, protein, fat, moisture, carbohydrate and energy were analyzed according to standard AOAC International methods. For the efficacy trials, eleven isonitrogenous diets containing 10% protein were formulated from six foods, maize (*Zea mays*), pearl millet (*Pennisentum glaucum*), finger millet (*Eleusine coracana*), sorghum (*Sorghum bicolor*), cassava (*Manihot esculentum*), and banana (*Musa* sp) at ratios of 70:30 flour and soy with milk powder as control and fed to weanling male albino rats. Another group was fed on a protein free diet. Protein Efficiency Ratio (PER), Food Efficiency Ratio (FER), Net Protein Retention Ratio (NPRR), True and Apparent Protein Digestibility, Protein Digestibility Corrected Amino Acid Score (PDCAAS) and growth were the indices of protein quality determined. Acceptability of porridges made from fortified flours was evaluated for colour, taste, texture, and smell by 50 consumers who were mothers and caregivers of young children using a 9-point hedonic scale. Soy fortification yielded a dramatic increase in protein content ranging from 63.25% in finger millet: soy to 797.63% in cassava: soy. Finger millet: soy had the lowest increase in oil content at 22.78% while the highest was 614.29% in pearl millet: soy. The increase in mineral content was lowest in banana: soy with 48.22% while maize: soy was on the highest with an increase of 562.65%. Banana: Soy diet had significantly superior protein nutritional quality, with a PER of 1.46, FER of 0.15, and NPRR of 0.48. Powdered milk had a PDCAAS of 100% while Maize: soy had 70%, the acceptable benchmark for foods for young children. Banana: soy recorded significantly high growth rate in rats with a weight gain of 32.27g while unfortified maize flour resulted in zero growth. True Protein Digestibility (TPD) of the fortified diets ranged from 88.81% in sorghum: soy flour to 95.59% in maize: soy flour, a range that is acceptable for cereal: bean mixtures. Sorghum soy had significantly high faecal bulk which was consistent with its low digestibility of 88.81%. On rehabilitation, the rats fed on protein free diet gained 45.10% on catch up growth. All the soy fortified porridges had total quality of above 65% and were also well accepted by the consumers. The findings show that soy fortified complementary flours have increased protein quality and nutrient density, and their porridges are acceptable to the target population. Fortification with soy improves PER of flours in rats, and by extrapolation could support growth of young children if used as complementary foods. It is recommended that soy fortified foods be used to alleviate PEM in Western Kenya.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

AGNHM	Australian Government National Health and Medical Research Council
AGRA	Alliance for a Green Revolution in Africa
AOAC	Association of Official Analytical Chemists
APD	Apparent Protein Digestibility
CBO	Community Based Organization
CIAT	International Centre for Tropical Agriculture
FAO	Food and Agriculture Organization
FER	Food Efficiency Ratio
FGD	Focus Group Discussion
ICRISAT	International Crops Research for the Semi-Arid Tropics
IFAD	International Fund for Agricultural Development
IFT	Institute of Food Technologists
IYCF	Infant and Young Child Feeding
IYCN	Infant and Young Child Nutrition
KARI	Kenya Agricultural Research Institute
KEPHIS	Kenya Plant Health Inspectorate Service
KSDS	Kenya Social Demographic Survey
MDGs	Millennium Development Goals
MNM	Micro Nutrients Malnutrition
NACOSTI	National Commission for Science, Technology, and Innovation
NGO	Non-Governmental Organization
NPRR	Net Protein Retention Ratio
NRC	National Research Council
PEM	Protein Energy Malnutrition
PER	Protein Efficiency Ratio
PDCAAS	Protein Digestibility Corrected Amino Acid Score
RDA	Recommended Daily Allowance
RDI	Recommended Dietary Intake
SOFI	State of Food Insecurity
TPD	True Protein Digestibility
TSBF	Tropical Soil Biology and Fertility
UNDP	United Nations Development program

UNICEF	United Nations Children’s Emergency Fund
UNU	United Nations University
USAID	United States Agency for International Development
USDA	United States Department of Agriculture
WB	World Bank
WFP	World Food Program
WHO	World Health Organization

ACKNOWLEDGEMENTS

I give thanks, glory, and honour to the Almighty God for providing me with the wisdom and perseverance to complete this study.

I would also like to extend heart-felt gratitude to the following individuals and/or parties who have been instrumental in the accomplishment of this work:

The VLIR-UOS AGBIO project for the partial tuition scholarship and funding of my work.

My lead supervisor, Dr. Charlotte A. Serrem for your patience and dedication while walking with me step by step through this work. Thanks for helping me organize my ideas academically and providing technical and expert review that helped in shaping my work. This work would not have been without you.

My second supervisor, Dr. Florence W. Wamunga for reviewing my work and giving insights that helped in improving it, and for constantly motivating my abilities which built my confidence. Thanks for your role in helping me secure the partial scholarship that eased the financial burden.

I salute Prof. Wanjiku Khamasi for inducting me into the world of research and my lecturers at the Department of Family and Consumer Sciences for shaping me as a scholar.

I most sincerely appreciate Mr. Edwin Kirwa, the laboratory technician at the Chemistry Lab II for the assistance in carrying out the chemical analyses and Mr. Apolonary Oucho for assistance in handling the laboratory animals. Your expertise and input in the respective areas was invaluable.

I am grateful to my entire family for the moral support and encouragement to pursue academic excellence. Your support urged me on even when the going seemed unmanageable. Special thanks to my brothers Symoh, Dan, and Sam for ever being so interested in my work; just one more step guys!

Thanks to my colleague and co-worker, Frederick B. Agengo for always being available and willing to share ideas. Thanks for the assistance in the experimental work and during the consumer evaluation panel. It was a great and humbling experience working with you.

I can never be grateful enough to all of you for your contributions towards this work. May God abundantly bless you all!

CHAPTER ONE

INTRODUCTION

1.1 Background Information

According to Food and Agriculture Organization (FAO) 2012b), about 12 million children aged below 5 years die on an annual basis. More than 50% of these deaths occur due to malnutrition. Millions of children in the tropical, subtropical, and least developed areas of the world suffer from malnutrition (Rai, Rai, and Pandey, 2007). Of these, children at the complementary feeding stage are most vulnerable (Onofiok and Nnanyelugo, 2010) because their macro and micro-nutrient needs might not be sufficiently provided for in the complementary foods (FAO, 2012b; Kramer et al., 2002). Additionally, low nutrient density of complementary foods further accounts for under-nutrition (Onofiok and Nnanyelugo, 2010). Under such circumstances, Protein Energy Malnutrition (PEM) as well as micro-nutrient deficiencies arise (World Bank, United Nations International Children's Emergency Fund, and World Health Organization (WB/UNICEF/WHO (2012).

PEM is the main form of malnutrition that affects young children. Though UNICEF (2012) statistics showed that prevalence of PEM in developing countries had reduced globally, the report by WB/UNICEF/WHO (2012) established that stunting, wasting, and underweight are still unacceptably high. Globally, about 165 million (26%) of children under 5 years of age were stunted by 2011, with 40% of children in the sub-Saharan Africa being stunted. Further, the rates of underweight were 16% (101 million), while wasting affected 8% (52 million) children (UNICEF, 2013). These high levels of PEM are a major cause of high infant and child morbidity and mortality rates (FAO, 2012a).

In Kenya, complementary feeding occurs from the age of 4-6 months (Nyaga, 2012). Although mothers might want to give their children proper complementary foods, they are incapacitated by high rates of food insecurity (United Nations Development Program (UNDP, 2012). In Western Kenya, this situation is aggravated by poverty. According to the Kenyan Social Demographic Survey (KSDS) 2009), the poverty level in Western Kenya stands at 57.9% for rural areas and 37.9% for the urban settlers. Among the places with high levels of poverty, hence food insecurity, are Siaya and Busia counties. The Human Immuno-Deficiency Virus/Acquired Immune Deficiency Syndrome (HIV/AIDS) scourge has also contributed greatly to infant and child malnutrition because HIV/AIDS positive mothers might not breastfeed as suggested by WHO (Kramer et al., 2002), thereby forcing them to use complementary foods. Infant diets are mostly cereal based with inclusion of roots and tubers (Onofiok & Nnanyelugo, 2010). Traditional vegetables are also employed (Kinyuru et al., 2012). These products are significantly low in protein, which is a major nutrient requirement for children at this age. Therefore, developing composite, nutrient dense complementary feeding products using locally available foods could be a solution to the complementary feeding problem among the rural households in Western Kenya (UNDP, 2012).

To improve the protein quality and nutrient density of complementary foods for young children, the FAO/WHO (1998) proposed the formulation of foods from root and cereal staples fortified with legumes. Soy bean (*Glycine max* L. *Merr)* a legume which grows well in Western Kenya, can be used to produce composite flours for preparation of acceptable and sustainable complementary foods. The nutritive value of soy bean is unique among legumes with a high protein content of 30 to 45% (USDA, 2012) compared to maize and cassava with 9.42% and 1.4%, respectively. Additionally, Vasconcelos et al. (2001) established that the indispensable amino acid profile of soy beans was comparable to the reference pattern for children aged 2 to 5 years. Soy bean true protein digestibility is also high, 75 to 97% in young children (Bodwell and Marable, 1981).

Efficacy of soy fortified complementary foods has been tried in other regions of the world using laboratory animals (Kure and Wyasu, 2013). Acceptability of soy fortified products has also been tested using human trials and has been successful (Olatidoye and Sobowale, 2011). There is limited information on such trials from Western Kenya. Therefore, the aim of the study was to investigate the efficacy of using soy flour as a fortificant in complementary foods from Western Kenya to improve infant and young child nutrition.

1.2 Statement of the Problem

A report on the State of Food Insecurity (SOFI) in the world by FAO, International Fund for Agricultural Development (IFAD), and World Food Program (WFP) 2013) indicated that in the period between 2011 and 2013, approximately 842 million people or 12% of the global population were affected by chronic undernourishment. Majority of these people live in the developing countries where 827 million individuals are affected (FAO, IFAD, & WFP, 2013). The challenge of malnutrition mainly affects women and children below five years of age. Children are mainly affected due to inadequate fetal nutrition and inadequate quality of complementary foods (FAO, 2012a).

Malnutrition is a challenge in Western Kenya. This is manifested in the form of PEM where stunting stands at 26.6%, underweight among children is at 13.9% whereas wasting is 10.1% (Nungo, Okoth, & Mbugua, 2012). Child malnutrition in Western Kenya is aggravated by the high levels of poverty which causes food insecurity (UNDP, 2012) and the prevalence of HIV/AIDS (Kramer *et al*, 2002; KSDS, 2008). Parents heavily rely on vegetables, roots, tubers and other starchy foods for complementary feeding (Kinyuru et al., 2012). This consumption of foods of low nutritional quality predisposes infants and young children to protein and micro-nutrient deficiency problems (FAO, 2012a). Though growth of soy bean has been widely promoted, cases of PEM still persist because the crop is grown more for commercial purposes than food (Jonas et al., 2008). Furthermore, there is limited information on soy fortification of complementary foods from Western Kenya and their protein nutritional quality. Adopting soy as a fortificant in complementary foods in Western Kenya and testing its efficacy in improving the nutritional quality of such foods would be a milestone in ensuring sound infant and child nutrition.

1.3 Objectives

1.3.1 Broad Objective

To determine the effect of soy fortification of complementary foods from Western Kenya on nutrient composition, protein nutritional quality, growth, nutritional rehabilitation, and consumer acceptability of the complementary foods.

1.3.2 Specific Objectives

i. To develop soy-fortified composite complementary flours using locally available foods from Western Kenya.

ii. To determine the effect of fortifying with soy on proximate and mineral composition of the composite complementary flours.

iii. To determine the effect of soy fortified composite flours on growth and rehabilitation in rats.

iv. To evaluate the protein nutritional quality of soy fortified composite flours.

v. To assess the consumer acceptability of porridge prepared using soy fortified composite flours.

1.4 Hypotheses

Ho$_1$: Soy fortified composite flours do not have significantly higher nutritional value compared to unfortified composite flours.

Ho$_{2:}$ Soy-fortified composite flours do not have a positive effect on growth and rehabilitation of rats.

Ho$_3$: Soy fortified composite flours do not have significantly higher protein quality than unfortified flours.

H$_{O4:}$ Soy fortification of flours used for making porridge in western Kenya has no effect on acceptability of the porridge.

1.5 Justification of the Study

The findings from this study are of great importance to parents of infants and young children in Western Kenya as it will inform them on how to choose and prepare nutrient dense, protein-rich complementary foods using locally available materials. The findings are also of interest to policy makers especially in the agricultural sector by informing them on the importance of promoting soy consumption. Lastly they can be used by nutritional advisors and researchers with an interest in modification of infant and young child diets to control incidences of PEM.

CHAPTER TWO

LITERATURE REVIEW

Introduction of complementary foods is a very important stage in a child’s nutrition, making Infant and Young Child Feeding (IYCF) a sensitive issue. This review highlights the challenge of child malnutrition, the IYCF practices, nutritional needs of infants and young children, and the challenges associated with complementary foods. It then gives an insight into the strategies adopted in improving these diets including soy-fortification as one of the approaches and the various efficacy tests already carried out on soy. It concludes by giving a situational analysis of soy growth and utilization in Western Kenya.

2.1 Malnutrition

According to UNICEF/WHO (2012), malnutrition can be broadly defined as "the cellular imbalance between the supply of nutrients and energy and the body's demand for them to ensure growth, maintenance and specific functions." This can be under-nutrition, over-nutrition, or unbalanced intake of nutrients. It can be caused by various reasons such as unavailability of food, inaccessibility of the food, malabsorption, and/or infections which can hinder adequate nutrient intake and absorption such as worm infections. UNICEF (2012) further notes that infant and young child malnutrition can be broadly classified into two groups namely Protein Energy Malnutrition (PEM) and Micro Nutrient Deficiencies (MNM).

2.1.1 Protein Energy Malnutrition (PEM)

According to UNICEF/WHO (2012), PEM is a term that applies to a group of disorders which include marasmus, kwashiorkor, and marasmus-kwashiorkor.

Marasmus is brought about by inadequate intake of proteins and calories. The term was derived from the Greek word ‘*marasmos*’ which means withering as the condition is manifested through emaciation. It is the body’s adaptive strategy to starvation.

Kwashorkor, on the other hand, is a maladaptive response to starvation. It is borrowed from the Ghanaian language meaning ‘the sickness of the weaning.’ It is brought about by poor intake of protein but with adequate intake of calories. PEM is a condition that affects many children across the world, accounting for half of the deaths of children aged below 5 years. There are three main anthropometric indices used in measuring PEM (UNICEF, 2012). Stunting is used to assess performance in terms of linear growth and is measured using height-for-age. It assesses chronic malnutrition. Body proportion is measured using weight-for-height and is an indicator of acute disturbances during growth such as effects of an infection. Lastly, there is weight-for-age which assesses the relationship between linear growth and body proportion.

2.1.2 Micro-Nutrient Malnutrition (MNM)

According to Allen, de Benoist, Dary, and Hurrell (2006), MNM, otherwise referred to as hidden hunger, is quite common in the developed nations but is highly prevalent in the developing nations. Though it can affect people in all age groups, women of child-bearing age and young children are at a higher risk. The most common forms of MNM include vitamin A, iron, and iodine deficiencies. Others include zinc, calcium, vitamin D, folate, and copper deficiencies among others. The deficiencies can be detected through clinical signs or through biochemical analysis. Allen et al (2006) indicate that MNM can contribute to high morbidity and mortality rates leading to high medical budget. This calls for measures to control the problem.

2.2 Infant and Young Child Feeding Practices

According to WHO/FAO/UNU (2007), the infancy and childhood stages are characterized by higher micronutrient and macronutrient requirements on a per-kilogram basis than any other stage of life. The increased needs are accounted for by the accelerated rates of cell division taking place in the course of development. This leads to an increase in the need for proteins, energy, and other nutrients required for DNA synthesis as well as the metabolism of proteins, fats, and calories. Adequate dietary intake at this stage is of great importance in ensuring lifelong health and well-being (WHO, 2013). To achieve this, it has been proposed that for the first six months of life, infants should be exclusively breastfed (WHO, 2007). This could help in attaining the optimum health, growth, and development, since the mother's milk has all the nutrients needed to meet the nutritional needs of the infant. Thereafter, there is need to ensure that the evolving nutritional needs of the infants are met through complementary feeding (Chan, 2013). As such, infants should receive complementary foods that are nutritionally adequate and safe. These should be combined with breastfeeding for up to two years of age and beyond (WHO, 2013).

Poor complementary feeding practices as well as challenges associated with complementary foods such as starchy and low nutrient density combinations are associated with poor infant and young child nutrition (Onofiok & Nnanyelugo, 2012). This has been attributed to a number of factors such as high bulk and low nutrient density in the complementary foods. In addition, early introduction of solid foods and unhygienic practices expose children to infections, growth retardation, and malnutrition (Nyaga, 2012); Rai, Rai, &Pandey, 2007). All these nutrition related factors lead to high infant and young child morbidity and mortality, accounting for about 50% of all deaths of children aged below 5 years (FAO, 2012).

Appropriate IYCF can help in addressing this problem. The international community has recognized this and advocated for the protection of every infant and child through the right to good nutrition as stipulated in the Convention of the Rights of the Child (WHO, 2013). Additionally, the WHO has further implemented and monitored the “Comprehensive implementation on maternal, infant, and young child nutrition” endorsed by member countries in 2012 (WHO, 2013). This strategy seeks to ensure that all instances of child malnutrition are comprehensively curbed.

Sound strategies have to be put in place to realize improved childhood nutrition. UNICEF and WHO have designed courses aimed at equipping health workers to provide professional aid to mothers, to enable them overcome problems encountered and monitor child growth so as to identify early signs of malnutrition (UNICEF/ WHO/WB, 2012).

According to WHO (2013), there are three steps aimed at realizing sound IYCF. First, there should be early initiation of breastfeeding within an hour after birth. Secondly, there should be exclusive breastfeeding for the first six months of life. Lastly, at six months of life, there should be introduction of nutritionally adequate and safe complementary foods. These should be given alongside breastfeeding and should run until the child is at least two years of age. To further emphasize the importance of sound IYCF, WHO (2003), in its Global Strategy for IYCF, proposes that adequate child nutrition should be a responsibility of individual governments. The administrative authorities should, therefore, take an upper hand in development and implementation of comprehensive policies on infant and young child feeding. This should be done in the context of the national policies for nutrition, poverty reduction, and child and reproductive health. To ensure that nutrient needs for infants aged 6-24 months are met, UNICEF (2011) suggests that foods should be chosen from the seven food groups; grains, roots and tubers, legumes and nuts, dairy products, flesh foods, Vitamin A rich foods and vegetables, and other fruits and vegetables.

2.3 Nutritional Requirements for Infants and Young Children

Due to the accelerated rates of growth in infants and young children, there is a proportional increase in their nutritional requirements (WHO/FAO/UNU, 2007). Consequently, there is need to ensure that such needs are met to avoid the malnutrition trap that has endangered the lives of many. A study by Kinyuru et al. (2012) found that most of these nutrients are effectively provided for in the infants and young children’s diets, with the exception of protein and some minerals.

2.3.1 Macro-Nutrients

Proteins are of great importance in infant and young children’s diets. This is because the protein helps in the rapid cell growth and development, tissue growth and replacement of worn out tissues, among others. Failure to meet the nutrient needs of such children can lead to failure to thrive. This is the challenge witnessed in many developing countries (Dewey, 2013) where instances of kwashiorkor, marasmus, stunting, and underweight are prevalent.

The WHO (2013) maintains that breast milk provides all the protein requirements for infants. Infants of 0-6 months need about 9.1 g of protein which is provided for in the breast milk. Between 6 months to 1 year, toddlers need about 11 g of protein per day. This can be selected from various protein sources including cheese, whole-milk yoghurt, cooked legumes, tofu, pureed meats, and egg yolks, among others. Between the ages of 1 and 3 years, children need about 13 g of protein per day. This can come from a wide range of meats, milk, and legumes. White meat like chicken, fish, and rabbit should be advocated for (Vaclavik and Christian, 2013). This can help in meeting the amino acid requirements for the infants and young children, which are shown in Table 2.1.

Table 2.1: Amino Acid Requirements and Scoring Patterns for children 0-5 to 2 Years (mg/kg/d)

Amino Acid	**Age**			
	Requirement		**Scoring Pattern**	
	0-0.5 Years	**1-2 Years**	**0-0.5 Years**	**2 Years**
Histidine	22	15	20	18
Isoleucine	36	27	32	31
Leucine	73	54	66	63
Lysine	63	44	57	52
Methionine	31	22	27	26
Phenylalanine	59	40	52	46
Threonine	35	24	31	27
Tryptophan	9.5	6	8.5	7.4
Valine	48	36	43	42

Adopted from: FAO (2011)

Fats are important in infant diets because young children need more concentrated energy than adults. The Australian Government National Health and Medical Research Council (AGNHM, 2014) notes that fats could be the best source of energy for infants and young children. This is because fats provide concentrated energy of about 37 kJ/g. Given that children cannot consume much food due to the small size of their stomachs, having such concentrated energy is quite important. Additionally, fats help in absorption of the fat soluble vitamins A, D, E, and K. However, caution should be taken to ensure that sources of unsaturated fats are incorporated into the diet. These should include plant sources such as avocadoes, oily fish, nuts, and seeds. Saturated fats which are common in fatty meat, cheese, and cream should be limited (WHO, 2013). A daily intake of about 30 mg/day and 40 mg/day is required for infants aged 6-12 months and 13-36 months respectively (AGNHM, 2014).

Dietary carbohydrate is also needed for proper child growth and development. The main function of carbohydrates in the body is energy provision especially to the brain cells that require glucose for metabolism. According to AGNHM (2014), during infancy, the brain size is large in relation to the size of the body. It consumes about 60% of the total intake of the infant. A carbohydrate intake of 95 g/day is needed for infants aged 7-12 months.

Energy is required for basal metabolism as well as daily expenditure on physical activities. According to (WHO/FAO/UNU, 2007), the energy needs for young children are quite high compared to that of adults. On average, an adult requires about 25-30 calories per kg body weight. However, an infant of about 4 kg needs about 100 kcals/kg which amounts to about 430 calories/day. Infants between 4-6 months who are about 6 kg in weight require approximately 343.088 kJ/kg. From 1 to 3 years of age, the children need about 347.27 kJ/kg. This translates into 4142.2 kJ/day. After the age of 3 years, the energy requirements can change depending on an individual's height, weight, and level of physical activity. It is, therefore, important to make sure that the energy needs of the young children are met so as to give them a good start in life. The Indian National Guideline (2004) indicates that good sources of energy include cereals, pasta, rice and bread, among others. Whole cereals should be used in order to reduce instances of overweight and obesity. In the diet, energy is derived from carbohydrates (16.7kJ/g), proteins (16.7kJ/g), and fats (37.7kJ/g).

2.3.2 Micro-Nutrients

Iron is an important mineral which forms part of important proteins such as myoglobin, haemoglobin, cytochromes, as well as enzymes which are involved in redox reactions in the body (AGNHM, 2014). The RDI of iron for infants aged 7-12 months and 1-3 years is 11mg/day and 9 mg/day respectively. Zinc is a component in many enzymes which ensure the structural integrity of proteins besides regulating gene expression. Its biological functions are catalytic, structural, and regulatory (Mosha and Vicent, 2004). It is found in various foods but the best sources are fish, meat, and poultry. Cereals contain a substantial amount of zinc. An intake of 3 mg/day is sufficient for infants and young children of up to 3 years.

Calcium, which is commonly found in milk and green leafy vegetables, is needed for the normal development and sustenance of the skeleton. Calcium’s RDI for infants of 0.5-1 year and 1-3 years is 270 mg/day and 500 mg/day respectively. The infants also need manganese which is involved in bone formation (AGNHM, 2014). It also plays a role in the metabolism of carbohydrates, amino acids, and cholesterol through its metallo-enzymes. The intake should be 0.6 mg/day for infants aged 7-12 months and 2.0 mg/day for those aged 1-3 years. Copper should also be incorporated in the diet to the tune of 0.22 mg/day for infants aged 7-12 months and 0.7 mg/day for those aged

1-3 years (AGNHM, 2014). Copper is important because it is a catalytic element, a crucial component in a number of metallo-enzymes.

2.4 Synergy between Sound IYCF and MDGs

According to UNICEF (2006), IYCF is essential in the attainment of the Millennium Development Goals (MDGs). Under-nutrition accounts for the deaths of about 5.6 million children on an annual basis. Furthermore, one out of every four children below five years of age living in the least developed countries is underweight. This implies that the children are at risk of early death. They are also prone to multiple infections. This necessitates the need to look at the importance of sound IYCF.

A report by FAO (2004) concluded that IYCF is largely related to the attainment of the MDGs. This is because all the MDGs are aimed at addressing core issues such as health, poverty, education, disease, social welfare, and hunger. Nutritional status is one of the principal indicators of all these issues. Therefore, by assessing the nutritional status in a given population, it is possible to estimate the extent to which the population is aligned to the attainment of the MDGs.

To further compound the problem, under-nutrition leads to delays in development of children from childhood to adolescents and ultimately into adulthood (UNICEF, 2007). It is with such concerns that the UNICEF strives to monitor and evaluate children’s progress towards the attainment of the MDGs.

The relationship between sound IYCF and the MDGs is undeniably relevant to sound young child nutrition. As FAO (2004) indicates, sound IYCF is highly related the

MDG 1 which seeks to eliminate extreme poverty and hunger. In order to achieve this, there are two major steps that need to be taken. First of all, there should be an improvement in agricultural productivity and promotion of better nutritional practices across all levels. Secondly, there should be programs which ensure that there is promotion of sound nutritional practices across all levels. This implies that the food security indicators of availability, stability, accessibility, safety, and utilization of nutritious foods are attained (FAO, 2004). This goal is related to IYCF because poor households cannot offer nutritious foods to their children.

Sufficient IYCF is greatly related to MDG 4 which seeks to reduce the child mortality rates. More than half of the annual deaths amongst young children can be attributed to malnutrition (FAO, 2012). As such, ensuring that there is adequate nutrition for the mothers and their children can aid in attainment of MDG 4. FAO (2004) indicates that good nutrition saves lives. As such, programs aimed at improvement of food security at household level as well as nutritional information can increase the chances of children to grow into adulthood.

2.5 Challenges Associated with Complementary Foods

Low nutrient density of complementary foods is the main challenge associated with complementary foods in developing countries (Mosha and Vicent 2004) and the main cause of under-nutrition amongst infants and young children. Some researchers have established that most complementary foods are low in protein content and have poor protein quality. For example, Kinyuru et al. (2012) conducted a study in Western Kenya and found that the infant and young child diets in the region are mainly cereal, root and vegetable based. The commonly used cereals included sorghum, pearl millet, maize, and amaranthus, while cassava root is used due to its abundance through-out the year as well as its drought resistance. Such foods are deficient in proteins and some minerals (USDA, 2010), a factor that predisposes the children to micro and macro-nutrient deficiencies.

Another challenge is the methods and resources used during complementary feeding. Nyaga (2012) investigated the manner in which complementary foods are introduced in Kenya, and reported that feeding starts at the age of 4-6 months. This is against the recommendation by WHO that complementary feeding should be introduced at the age of 6 months (WHO, 2013). According to Nyaga (2012), water and cow milk are used as the initial complementary foods. However, this is gradually followed up with a thin gruel made from cereal flour which might not contain adequate protein to satisfy the protein needs of infants. Similarly, a study by Onofiok and Nnanyelugo (2012) found that people in the low economic groups rarely feed their children on animal sourced foods such as eggs, meat, and fish as they are too expensive for them to purchase. Additionally, recommended commercial complementary foods are also beyond their financial access. This is a challenge because animal sourced foods are the best sources of bioavailable protein (Nicklaus, 2011). Poor timing during the introduction of complementary foods is another factor which inhibits the potential of such foods to meet the nutritional needs of infants. A study conducted by van der Merwe, Kluyts, Bowley, and Marais (2007) found that untimely and inappropriate introduction of complementary foods is a risk factor for both over and under-nutrition. The study agreed with the findings by Nyaga (2012) that solid foods are introduced at the age of 4 months or younger. Timely and appropriate introduction of complementary foods has a long-term impact on the health and developmental aspects of young children. It is for this reason that van der Merwe et al. (2007) conclude that the timing should be appropriate so as to make sure that children get the optimal benefits from complementary foods.

A third challenge is that many infant diets do not incorporate legumes such as beans (Nicklaus 2011) which are relatively cheap sources of protein. This is because of the indigestibility and flatulence issues that are associated with legumes (Riaz, 2012) making many mothers shy away from feeding legumes to their children. A similar observation was made by Ogunleye and Omotoso (2005) who concluded that though there are different types of legumes available in developing countries, yet many parents do not use them to feed their children due to the fear of flatulence.

Lastly, a study by Dewey (2013) reported that a major set-back for the complementary foods in developing countries is low mineral bio-availability. The study established that due to the high concentration of cereals in complementary foods, there is a higher chance of phytic action making the minerals in the foods unavailable. This precipitates into deficiencies of some nutrients such as iron among others. Therefore, to ensure the efficacy of the largely cereal-based complementary foods in the developing countries, the challenge of low mineral bioavailability has to be addressed.

2.6 Boosting the Protein Content in Infant and Young Child Diets

WHO (2013), proposes that the proper IYCF practices need to be adhered to in order to ensure that children grow up healthy. This can only be realized when the quality of complementary foods is improved to match the nutrient needs of the infants and young children. There are various strategies that can be adopted in improving these complementary foods.

2.6.1 Dietary Diversification

This involves increasing both the amount as well as the variety of foods eaten (Allen et al., 2006). This calls for the implementation of programs which ensure that there is availability, accessibility, and utilization of different types of foods which includes fruits, vegetables, and animal products. This strategy can help in improving the nutrition status of a population because it encourages the intake of various food constituents. As a result, it can help in controlling both the macro and micro-nutrient malnutrition. This is an option that can be explored in improving the complementary foods. Lack of resources to produce the diversified foods can be a barrier to adoption of this strategy. It is for this reason that locally available and affordable resources should be used (Onofiok and Nnanyelugo, 2012).

2.6.2 Food Fortification

According to FAO/WHO (2002), food fortification refers to the addition of micronutrients to foods that are already processed. It is a food based approach that can be used in instances when the food supplies as well as limited access lead to inadequate levels of the respective nutrients through complementation. It is mainly used in controlling micro-nutrient deficiencies where the deficient element is added to the food during processing. This strategy can be used in rapidly improving the micro-nutrient status of a population at an affordable cost because it makes use of the already existent infrastructure and technology. Centrally processed food vehicles are used in the fortification process. The fortificant, on the other hand, should not tamper with the sensory properties of the food vehicle. The level of fortification should also be within the limits set by the Codex Alimentarius Commission for food fortification for young children (FAO/WHO, 2002).

Cereals and other starchy foods that are used as staples are preferred as fortification vehicles. Onofiok and Nnanyelugo (2012) further support this idea by concluding that though cereals are deficient in lysine, they have sufficient amounts of sulphur-containing amino acids which are found in lesser amounts in legumes. As such, a combination of cereals and legumes yields amino acid patterns that are sufficient to promote growth.

2.6.3 Supplementation

Allen et al (2006) describe this as a process through which considerably large doses of micronutrients are provided. These can be in form of capsules, pills, or syrups. This strategy helps in the provision of the optimal amounts of the target nutrients and in the most absorbable form. The strategy is commonly employed in developing countries where interventions seek to boost the intake of vitamin A.

2.6.4 Other Measures

Other strategies that can help in improving the complementary diets include adoption of plant breeding technologies which lead to production of foods with high nutrient density (Allen et al., 2006). Empowerment of women both financially and through imparting knowledge can equip them with skills on how to prepare proper foods for their children (Onofiok and Nnanyelugo, 2012). This can be ensured through social protection measures.

2.6.5 Complementation in Action

People from different parts of the world have adopted the fortification strategy in efforts to boost the protein content in infant and young child diets. Traditional foods that are readily available are used. In an effort to improve the protein quality of complementary foods in Africa, researchers have developed infant and young child food products using the principle of complementation. When the relative deficiency of an amino acid in one protein is compensated by a surplus from another protein consumed at the same time, complementation is achieved (Bender, 2005). For instance, combining cereals and legumes where one supplements the other with the deficient amino acid creates a balance that results in nutritional complementation (Young and Pellet, 1994).

Mosha and Bennink (2004) carried out a study seeking to evaluate the protein quality of cereal-bean-sardine composites for their efficacy in supplying the nutrient needs for children of pre-school age. Results from six composite flours using cereals, beans, and sardines showed that rice meal-bean-sardine composite increased net protein retention ratio and PDCAAS by 39.39% and 53.45% respectively. Similarly, corn-bean meal-sardine composite increased net protein retention ratio by 207.14% and PDCAAS by 63.83%.

Aremu, Osifande, Basu, and Ablaku (2011) used kersting’s groundnuts to fortify Ogi, a maize meal product popularly used as a complementary food in west Africa at ratios of 90:10, 80:20, 70:30, and 60:40 with 100% maize: groundnuts. The fortified ogi had an indispensable amino acid content of 26.4-32.6 g/100 g and crude protein which represented 47.9-48.4% of the total amino acids. The researchers concluded that complementation of maize with 30% kerstingiella seed for preparation of ogi can be maintained with an increased nutrient content and quality.

Fortification with soy is also an option that has been explored. A study by Serrem et al (2011) utilized soy as a fortificant in improving sorghum flour. The protein quality indices of the sorghum: soy composite flour were significantly higher than pure sorghum. The increment in the apparent digestibility was 4.27% while true digestibility increased by 4.1%.

Based on these findings, it is apparent that composite flours comprise one of the ways that can be adopted in ensuring that the complementary foods are protein sufficient. The Codex Alimentarius Commission of the United Nations recommends compositing of legumes and starchy staples as a means of improving the nutrient quality of foods for young children (FAO/WHO, 2002). Different protein sources can be used as fortificants in the complementary foods depending on the availability, accessibility, and acceptability. The fortificants can, therefore, vary depending on the ecological zone, food cultures, and beliefs of different people. Identification of a suitable fortificant that is acceptable and sustainable by a majority of the population is important. Soy bean is such a fortificant (Onofiok & Nnanyelugo, 2012).

2.7 Soy as a Fortificant

Soy bean is a legume species which originated from East Asia (USDA, 2012). Due to the various uses and products that can be derived from soy, it is often classified as an oilseed rather than a pulse. The main producers of soy bean in the world include the United States of America (USA) which produces 35%, Brazil at 27% and Argentina which produces 19%. Other leading producers are China and India which stand at 5%and 4%, respectively. The USA constitutes the largest consumer of soy bean (US Department of Agriculture, 2012).

Various food products have been prepared using the soy bean. Some of the traditional non-fermented foods made from soy include tofu, soy milk, and tofu skin (Chen, 2012). There are other fermented foods which include nato, tempeh, fermented bean paste, and soy sauce. All these products are high in nutritional value, especially the protein content. Soy is popular because of its nutritional benefits. According to USDA (2012), the nutritive value of soy bean is much higher than other staple foods. Soy is particularly high in protein content which can be up to 34.5% compared to other legumes and cereals such as cassava and maize with 1.4% and 9.42%, respectively (USDA, 2012). Soy is, therefore, used by many as an alternative source of protein and is recommended for use by vegans as its protein quality is comparable to animal protein (Shidfar et al., 2009).

There are other nutritional benefits associated with the use of soy bean as a food. It has anti-oxidant properties which make it effective in preventing some degenerative diseases such as cancer. According to Shidfar et al. (2009), post menopausal women often have an unfavorable serum lipoprotein profile which puts them at risk for cardiovascular diseases. Consumption of soy-bean can help alleviate this problem by a margin of 9.7% due to the presence of flavonoids (Lee et al., 2011). Given these nutritional benefits, soy bean has been widely used in improving the nutritional quality of foods.

Despite its nutritional benefits, soy also has some anti-nutritional factors. In a study comparing total phenols, flavonoids, saponins, and anti-oxidant activity in soy beans and mung beans, Lee et al. (2011) reported that soy has phenolic compounds, trypsin inhibitors, and hemagluttinins. Compared to other legumes such as mung bean, soy has about 4.5 times more sapponins (Lee et al., 2011). These factors can greatly reduce the bio-availability of some nutrients in soy, particularly proteins which are affected by the trypsin inhibitors (Riaz, 2012). Due to this problem, there is need for special treatment of soy before use in diets (Riaz 2012). Dry heat treatment in an oven, steaming and boiling are some of the methods employed to deactivate anti-nutritional factors in soy bean (Riaz, 2012).

To address the problem of low nutrient density of infant foods, soy bean has been used to improve the protein content (Aremu *et al*., 2011) and amino acid profile (Kure and Wyasu, 2013) of traditionally used foods in developing countries. This is attributed to its superior amino acid profile.

Table 2.2 shows that cereals also do have a considerable amount of essential amino acids. However, there are some factors which make cereals not very good sources of protein. First, cereals have phytates (Aremu et al., 2011). These bind the amino acids, lowering their bio-availability. Secondly, cereals have poor protein quality due to low lysine content as evidenced by the USDA (2012). This implies that in order to get the required amount of amino acids a large quantity of cereals have to be consumed to make up for the lower protein content and also compensate for the inhibitory factors.

Table 2.2: Comparison of Essential Amino Acid Profiles in Different Foods (mg/100 g of protein)

Amino Acid	**Sorghum**	**Soy**	**Cassava**	**Maize**	**P. Millet**	**Banana**	**Milk Powder**	**F. Millet**
Histidine	19.82	24.6	14.71	30.45	21.42	70.64	27.13	19.77
Isoleucine	36.59	44.3	19.85	35.79	42.20	25.69	60.51	36.38
Leucine	128.72	74.4	28.68	122.66	127.04	62.39	97.95	118.23
Lysine	20.58	60.8	32.35	28.14	19.24	45.87	79.31	24.49
Methionine	17.15	12.33	8.09	20.92	20.05	7.34	25.08	24.54
Phenylalanine	52.35	47.67	19.12	49.06	52.63	44.95	48.29	51.92
Threonine	36.98	39.68	20.59	37.66	32.03	25.69	45.13	27.23
Tryptophan	12.58	13.28	13.97	7.07	10.80	8.26	14.10	13.08
Valine	45.87	45.61	25.74	50.5	52.45	43.12	66.92	44.92
Protein Content	7.87	37.80	1.36	6.93	11.02	1.09	36.16	13

Adopted from: USDA (2013)

Starchy fruits, tubers, and roots are also used as a main component of infant diets (Kinyuru et al., 2012). However, the amino acid profiles by FAO (1981) and Nassar and Sousa (2007), show that these foods are greatly limited in protein content and essential amino acids. This is, therefore, an indication that such foods cannot satisfy the protein and amino acid requirements for the different groups of people as indicated by WHO/FAO/UNU (2007). Consequently, FAO (2002) advocates for complementation of the starchy foods with legumes as a way to improving bio-availability of the proteins and amino acids. Complementation with legumes raises the protein quality in cereal-based foods.

2.7.1 Protein Quality of Soy

There is evidence that soy fortification can be used to improve the protein quality of foods. A study by Kure and Wyasu (2013) who fortified sorghum flour with soy for gruel preparation showed there was improvement in the amino acid pattern of the composite flour which had increased levels of lysine, methionine, and tryptophan. Additionally, the resultant gruel had better physico-chemical properties compared to pure sorghum flour.

A similar study was carried out by Serrem et al. (2011) where sorghum was fortified with soy and tested for efficacy in controlling PEM. The results of the study indicated that the Protein Efficiency Ratio (PER) of the fortified flour was similar to that of casein. This was also the case for the Net Protein Utilization (NPU) as well as the Biological Value (BV) of the fortified flour. These researchers concluded that soy fortified biscuits have the potential, to control PEM.

Fortification of composite flours with soy has been tried with other foods rather than cereals. Olatidoye and Sobowale (2011) reported that a composite flour of soy and cassava was used to develop value added fufu in Nigeria. The result was that a more nutritious meal was prepared which could help in improving food security in the region. Sensory evaluation and biochemical tests showed that the product had a higher nutrient content and improved organoleptic and biochemical qualities.

With this evidence, therefore, it is conclusive that soy can be used as a fortificant in different foods. As a legume of superior nutritional quality, it can be used in improving the nutritional content and quality of different foods. This is an option that needs to be explored so as to deal with the existing nutritional problems especially PEM (Onofiok and Nnanyelugo, 2012).

2.8 Evaluation of Protein Quality

2.8.1 Controlled Trials of Soy Fortified Complementary Foods

Developing of composite flours implies that new or modified mixtures have to be derived. These are mixtures which have not been used or tested in the past. As such, their chemical, physical, and functional characteristics might not be well known. Furthermore, their effects on health of the users cannot be ascertained unless the composites are effectively tested. Additionally, there are regulations in different countries as to the levels that food grade items should attain.

All these considerations and requirements have to be fulfilled before the products are released into the market. In this regard, WHO/FAO/UNU (2007) suggests that animal models, for example rats, should be used in testing such products. This is because the metabolic and digestive processes in the rats which are monogastric are similar to that of humans. However, rat bio-assays have a back-drop in that the studies are based on the amino-acid requirements of rats rather than that of humans (FAO/WHO, 1991). Therefore, these studies can be misleading because rats have a much higher sulphur-based amino acid requirement as compared to humans. To solve this problem, FAO/WHO (1991) recommends that such studies should be solved by direct comparison of food proteins to the amino acid patterns for humans. Consequently, studies aimed at testing human food have been carried out following these guidelines.

2.8.2 Protein Digestibility Corrected Amino Acid Score (PDCAAS)

This is a method that is used in determining the quality of proteins in a food (WHO/FAO/UNU, 2007). It was recommended as a method of evaluating protein quality in an FAO/WHO consultative meeting in 1985. The other commonly used method of evaluating protein quality is the Protein Efficiency Ratio (PER). This method might not be efficient since PER cannot be used to effectively predict the credibility of protein used for maintenance purposes (FAO/WHO, 1991). A protein might score a low PER and might not support growth but might be adequate for maintenance purposes. This led to the adoption of PDCAAS as the method of evaluating protein quality because it looks at the ability of a protein to provide the required amino acids and nitrogen required by the human body (FAO/WHO, 1991).

PDCAAS can be used in evaluating the protein quality in complementary foods. To compute the PDCAAS, digestibility of a food must be determined either in-vivo or in vitro. A challenge identified with this procedure is that it is difficult to experimentally carry out digestibility studies using young children due to the ethical issues involved as well as the cost (FAO/WHO, 1991). As a result, rat assays are used in assessing the protein quality in such foods as they are more sensitive when the rats feed entirely on the experimental diet. A short-coming of such trials is that rats have a higher amino acid requirement than infants and young children. In order to qualify and add credibility of the use of PDCAAS in evaluating the protein quality of complementary foods, WHO/FAO/UNU (2007) established that the PDCAAS score of a food should be associated with the amino acid requirement pattern for the subjects in a particular age group. The Codex Alimentarius Commission has set the PDCAAS for infant and young children diets at 70% (FAO, 2002).

2.8.3 Efficacy studies on fortified complementary foods

Some researchers have used rat studies to determine the quality of fortified foods. For instance, Serrem et al (2011) conducted a rat bio-assay aimed at determining the protein quality in soy-fortified sorghum biscuits using male Sprague Dowley rats. The researchers established the differences in protein quality for four diets using the protein digestibility corrected amino acid scores (PDCAAS) as the index of protein quality. The results showed that complementing sorghum with soy led to an improvement in PDCAAS from 26% to 87% for children aged 3 – 10 years and 24% to 87% for children aged 1 – 2 years of age. A similar study by Asemi et al. (2012) evaluated the efficacy of two brands of cerelac in controlling PEM. Three diets, which included the cerelac (commercial complementary food) based on rice with milk and Ghoncheh (commercial complementary food) based on milk rice with milk, were fed to weanling Wistar rats. These researchers determined that protein quality indices values were higher in celerac than in Ghoncheh: TPD was 19.79% higher, NPR was higher by 17.75%, and PER was higher by 58.57% showing that celerac was superior to Ghoncheh.

Animal model controlled trials are also used in testing animal feed. A study by Ogunleye and Omotoso (2005) investigated the effectiveness of Orthopteran (*Zonocerus varigatus*) and Lepidopteran (*Cirinaforda*) as possible substitutes for fish meal in conventional feeds. The researchers concluded that the two insects could be used as substitutes for fish meal in conventional feeds following the evaluation of two experimental diets and a control diet of grower's mash.

Based on these studies, it is evident that animal models are very important in testing new products before they are introduced into the market. This is because there can be absolute control of the experimental variables (FAO/WHO, 1991), thereby coming up with precise predictions on the interactions of the variables.

2.8.4 Consumer Acceptability Tests

Sensory evaluation is defined as a scientific discipline used to evoke, measure, analyze, and interpret reactions to those characteristics of foods and materials as they are perceived by the sense of sight, smell, taste, touch, and hearing (Institute of Food Technologists (IFT), 1981). Conducting consumer acceptability tests is important for a new product to ensure that it meets its objective when introduced into the market because a product shunned by consumers would definitely not meet the expectations (Lawless and Heymann, 2010). The IFT (1981) indicates that such tests should be carried out under various circumstances such as new product development, product matching, product improvement, process change, quality control, and product rating or grading. For example, Drake, Gerard, and Chen (2000) using a consumer acceptability panel, found that soy fortified yoghurt was not as well liked as regular yogurt. Given this information, complementary foods fortified with soy have to undergo the consumer acceptability tests before they are fully approved.

2.9 Soy in Western Kenya

According to the KNDS (2009), Western Kenya is one of the regions in the country where poverty has hit hardest, with levels of 57.9% in the rural areas. The area is also greatly affected by the HIV/AIDS scourge. As a result, food security in the region is highly compromised, a factor which predisposes the children here to PEM and its related complications (Nungo, Okoth, and Mbugua, 2012). Due to these poverty levels, many parents cannot afford animal proteins for their children which results in utilization of starchy foods such as cassava and other cereals (Kinyuru et al, 2012). An alternative protein source has to be adopted in order to deal with this problem. Soy bean arises as the crop of choice because Western Kenya accounts for about 50% of all soy beans produced in Kenya (Jonas et al., 2008).

The leading soy-production areas in the Western Kenya region include Busia, Bungoma, Teso, Butere/Mumias, Kakamega, Mt. Elgon, Lugari, and Vihiga (ICRISAT, 2013). The estimated area that is potentially viable for soy production ranges from 157,000 ha to 224,000 ha (ICRISAT, 2013). Factors that favor soy bean production in the region include the presence of viable and suitable soy-bean varieties, the extensive local demand for improved soy-bean seeds and grains, as well as the presence of experienced seed growers who reside within the community (Collombet, 2013). Other factors that can be exploited in intensification of soy bean production in Western Kenya include availability of research capacity in the country as well as sound policies such as the agricultural flagship project under the Vision 2030 which encourages and enhances innovative seed systems (Mahasi et al., 2012).

ICRISAT (2013) further reports that the seed system seeks to ensure that small holder farmers have access to improved seed varieties. This is being enhanced by a new integrated seed system approach where community based seed production will be crucial. This approach is also adopted by the Kenyan Seed Act. Jointly implemented by CIAT, the seed department of the Kenya Agricultural Research Institute (KARI – Kakamega), and KEPHIS under the Western Seed Growers Association (ICRISAT, 2013), this initiative has also come up with measures to improve and sustain soy production in Western Kenya (ICRISAT, 2013).

According to AGRA (2013), farmers in Western Kenya have lately witnessed an economic boom based on soya, groundnuts, and cowpeas. Soy is preferred to the others because it is more resistant to diseases and pests. Seed bulking for the crop has been adopted in three regions of Western Kenya; Busia, Siaya, and Teso (AGRA, 2013). Despite the fact that Western Kenya is the main producer of soy beans in Kenya, there is low consumption of the crop. This can be attributed to the laborious preparation and cooking methods, lack of knowledge and skills in soy preparation, lack of awareness of the nutritional benefits of soy, and the fact that many look upon soy as a commercial crop (Jonas et al., 2008). This is despite the fact that cases of PEM are high in the region. It is for this reason that soy complementation of complementary foods in the region is a viable idea because the soy beans are readily available and there is need to identify means of using them to solve the problem of poor quality diets for complementary feeding.

2.10 Conclusion

Based on this review, poor protein composition and quality of infants and young child diets is a problem in developing countries including Kenya. There are various efforts aimed at solving this problem. However, the problem has persisted. The challenge specifically affects children from households in the low income bracket as they cannot afford animal sourced protein foods and commercial complementary foods. The children are fed more of the starchy foods which are bulky but not nutrient dense. Composite flours of starchy staples and legumes could be used to make complementary foods to address this problem. Soy is suitable legume as it has the highest protein content among legumes besides having other nutritional benefits.

Despite the benefits associated with soy and its extensive production in Western Kenya, its use in households for complementary feeding is limited. Its adoption into the family diet has not been as effective, even in these areas where it can be easily grown. This study seeks to fill this gap by proposing ways through which the utilization of soy in addressing the nutritional challenges in the region can be promoted. This will be done through the use of soy in preparation of composite flours which can be used as cost-effective and accessible complementary foods in Western Kenya.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Materials

Samples of the six foods commonly used in Western Kenya for complementary feeding as identified by Kinyuru et al. (2012) were purchased from farmers in Western Kenya. These included maize (*Z. mays*), red, high tannin sorghum (*Sorghum bicolor*), finger millet (*Leusine carocana*), pearl millet *(Pennisetum glaucum),* dried cassava *(Manihot esculenta*), and raw cooking bananas (*Musa acuminata*). Soybean (variety SB-19) was obtained from farmers in Siaya County.

In addition to the requirements for the composite flours, skimmed milk powder (Miksi®, Promasidor Ltd, Nairobi, Kenya) containing 30% protein, corn oil (Elianto®, BIDCO Oil Refineries Ltd, Thika, Kenya) and corn starch (Zesta Corn Starch®, Trufoods Ltd, Nairobi, Kenya) for the rat study were also purchased in Eldoret.

3.2 Methods

3.2.1 Preparation of Composite Flours and Complementary Foods

Two explorative FGDs sessions one in Bungoma and the other in Busia each lasting 40 minutes were conducted on 7th and 8th December 2013, respectively. The aim was to find out how the people of Western Kenya prepare their composite flours and how they cook the complementary foods. The respondents who came from farmer groups in the two regions were identified with the help of a local research guide. Each FGD was made up of 10 people with 7 female and 3 male participants (Witteman, Spaanjaars, and Arts, 2012) aged between 32 to 52 years. The choice for a higher number of females was because they are more frequently involved in food preparation. Both sessions were carried out in a farmer's homestead identified by the participating farmers and the guide. The sitting arrangement was circular. The proceedings of the sessions were recorded using a video camera and some observations also noted down. The information gathered was used in the preparation of the food samples. The questions addressed in the FGDs were as follows:

i. At what age do you introduce other foods to your children apart from breast milk?
ii. What types of food do you give to these children?
iii. Which cereal flours do you use in preparing children's porridge, in order of popularity?
iv. How often in a day are the children fed?
v. Which flours do you use to prepare children's porridge, in order of popularity?
vi. Do you mix the flours?
vii. If yes, which are the mixtures?
viii. How is the mixing done?
ix. Briefly describe the procedure you use to prepare porridge.
x. Would you like to know how soy can be added into the children's food?

3.2.2 Tests of Validity and Reliability

External validity of the study was ensured by having an FGD in a real life setting and by choosing a representative sample in a real life setting. Content validity of the FGD guide was ensured by the fact that it was prepared specifically for the current study and pre-testing it at the University of Eldoret Food Laboratory using 6 post-graduate students through simulation of the actual FGDs. The pre-testing was done before the actual FGDs were carried out. Reliability of the FGD guide was ensured by having the researcher conducting both FGDs, hence there was consistency.

3.3.1 Processing of Complementary foods

All the grains; maize, sorghum, pearl millet, finger millet and soy beans were cleaned and winnowed to remove any extraneous material. The dried cassava was also cleaned and cut into smaller pieces. The green bananas were peeled and chopped into small pieces. These were sun-dried for 3 days to reduce moisture content to approximately 10%.

Preparation of the soy flour as the fortificant was done using the method of Riaz (2006) to neutralize the anti-nutrient factors by heat treatment. The soy beans were washed and sieved. The clean beans were then dried in an oven at a temperature of 75^{0}C for 1 hour in order to bring the moisture content down to about 10% (Riaz, 2006). After drying, the beans underwent tempering by putting in a pre-heated oven for about 72 hours so as to stabilize the moisture content. This was followed by a second cleaning through sieving and grinding. The rest of the grains, dried bananas and cassava were milled separately using a commercial hammer mill (Powerline®, BM-35, Kirloskar, India) in Eldoret town, fitted with a 2.0 mm opening screen. The six flours were composited using the methods realized in the FGD while incorporating soy flour as a fortificant.

3.3.2 Formulation of Flours

Formulation of the complementary food flours was based on the method used by (Kure and Wyasu, 2013) of 30% soy flour in the complementary food. Therefore the ratio used was food flour: soy flour 70:30 for each of the foods; maize, pearl millet, finger millet, cassava and banana to make six composites. A seventh composite of finger millet and soy at a ratio of food flour: soy 50:50 (to increase protein content) was also prepared for use in assessing the ability of soy-fortified products to rehabilitate malnourished individuals. To prepare the seven composite flours, each individual food flour was sieved into a bowl, the soy flour added and mixed using an electric mixer (Kenwood® Chef, KMC 200, Kenwood Co. Ltd, UK) at medium speed for 2 minutes. The flours were then transferred into air tight plastic containers and mixing completed by physical shaking of the containers which were stored at ambient temperature until required for chemical analyses, diet formulations and porridge production. Six unfortified flours were also stored in a similar manner to make a total of 13 test samples.

3.4 Experimental Design

Laboratory experiments were used for the chemical analysis in determining the proximate composition of the foods. Experiments were carried out in triplicates on three different days and the average value was used. Thirteen samples were analyzed for 4 parameters. Six of the samples were also subjected to elemental analysis for four parameters. All the analyses were carried out in triplicates, making up to 228 samples.

The growth, rehabilitation, and digestibility studies were carried out using the Complete Block Design (CRD). Rats were randomly assigned to the treatments based on their weights. There ten treatments each replicated four times. The rats were the replicates while the different diets were the treatments.

The consumer acceptability tests were also carried out using central location consumer test which best suits the CRD approach. Numeric codes were randomly assigned to the samples for blinding purposes and sample arrangements on the set-up trays were also randomized for each panelist. The panelists also came in at random to conduct the acceptability tests.

3.5 Proximate Analyses

3.5.1 Moisture Content

Moisture content of flours was determined using the oven drying procedure (AOAC International, 1995) Method 934.01. About 2 g of the samples were dried in an oven (Memmert, UNB 300, Schutzart, Germany) to constant weight at 105^0C for $3^1/_2$ hours, cooled in a desiccator and weighed. The loss of weight was calculated as percent of sample weight and expressed as moisture content. The percentage moisture content was then calculated as follows:

% Moisture = (weight moisture in sample x 100)/ weight of sample.

3.5.2 Crude protein

Crude protein was determined by the micro Kjeldahl method (AOAC International, 1995) Method 984.13. A sample of 0.3 g of each of the flours was digested in a heating block (Digester system 20, Type 115, Milano, Italy) at $370\text{-}400^0$C for about 60-90 minutes or until the contents became clear. In 0.2 ml of the digested sample, 5ml of a previously prepared N1 mixture was added and allowed to stand for about 15 minutes before 5ml of N2 was added. The mixture was allowed to stand for one hour during which it developed a blue color whose absorbance was read off a spectrophotometer (Spectronic 21D, MILTON ROY, AKIU®, Germany) at 650 nm. The absorbance values were used to read off the %N from a graph plotted using standards (Okalebo, Gathua, and Woomer, 2002). The %N in the sample was calculated using the formula:

$$N\,\% = \frac{(a-b) \times v \times 100}{1000 \times w \times al \times 1000}$$

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).

3.5.3 Crude Oil

Crude oil content was determined using the Soxhlet extraction method (AOAC International, 1995) Method 920.29. Samples of 2 g were weighed into a thimble and oil was extracted using petroleum ether as solvent for 8 hrs. The extract was oven-dried at 105^{0}C for about 30 minutes, cooled in desiccators, and weighed. The oil content was determined using the following formula:

Oil = Weight of flask with oil – Initial weight of flask

$$\%\ \text{Oil} = \frac{\text{Oil content (g)}}{\text{Sample weight}} \times 100$$

3.5.4 Ash determination

Ash was determined using (AOAC International, 1995) Method 923.03. Samples of 2 g of the food sample were burned at 500 – 600^{0}C for 6 hours in a muffle furnace (Carbolite 530 2 AU, Bamford, Sheffield, England) to constant weight. The samples were cooled in desiccators and weighed. Ash content was determined using the following formula:

Ash = (Weight of crucible + sample) before heating - (Weight of crucible + sample) after heating.

$$\% \text{ Ash} = \frac{\text{Ash content (g)}}{\text{Sample weigh}} \text{ X } 100$$

3.5.5 Carbohydrates Content

The percentage of carbohydrate content was calculated by difference (FAO/WHO, 1998).

% carbohydrates = 100 – (% oil + % moisture + % ash (minerals) + % protein)

3.5.6 Energy content

The energy content was calculated using the Atwater conversion factors (FAO, 2003) which are 16.736 for carbohydrate and protein and 37.656 for oil. Therefore, the total energy in the diet was determined using the following formula:

(kJ) = (% carbohydrates x 16.736) + (% protein x 16.736) + (% oil x 37.656).

3.5.7 Mineral Analysis

Zinc (Zn), Iron (Fe), Manganese (Mn), and Copper (Cu) were analyzed using the Atomic absorption spectrophotometry (AAS) (AOAC International, 1995) Method 985.35. The samples that had been digested for crude protein were atomized and their concentration read off against the standards for each mineral. The concentration was obtained in mg/L.

3.6 Evaluation of Protein Nutritional Quality Using Animal Model (Rats)

3.6.1 Flour Samples

Nine types of flour were used in this study. Six were made of maize, sorghum, pearl millet, finger millet, cassava and banana composited with soy at a ratio of 70:30. The seventh sample was made of finger millet composited with soy at a ratio of 50:50 while the eighth and ninth samples were 100% maize flour and 100% finger millet flour, respectively. They were prepared using the procedure described in Chapter 3 (section 3.2).

3.6.2 Diet formulation

A total of eleven (11) diets were formulated. These included 6 soy fortified diets at complementary food to soy flour ratio 70: 30, two unfortified diets comprising of pure maize flour and pure finger millet flour respectively, a protein free diet, and a skimmed milk powder diet (Table 3.2). The eleventh diet, meant for rehabilitation, was made up of finger millet with soy at a ratio of 50:50. These diets were formulated as outlined in the AOAC International (1995) Method 960.48 with modifications. The proximate composition for the flours(Table 3.1) as determined by chemical analysis was used to calculate the percentage of ingredients in each diet formulated.

Table 3.1: Proximate Composition of Unfortified and Soy-Fortified Composite Flours (g/100 g)

	Ash	**Moisture**	**Oil**	**Protein**
Flours				
Maize	0.83	10.17	4.33	9.48
Finger Millet	1.67	9.17	7.33	12.38
Composites				
Cassava + Soy	5.50	8.50	9.67	15.17
Maize + Soy	5.50	9.33	11.33	17.41
Sorghum + Soy	5.17	9.17	10.00	18.43
F. Millet + Soy	5.83	9.00	9.00	20.21
Banana + Soy	6.67	10.17	9.83	14.59
P. Millet + Soy	6.7	9.17	9.50	18.06

Source: Own Compilation based on Proximate Analyses

Nine diets which were isonitrogenous, containing 10% crude protein each were prepared from the eight sample flours and milk powder. The milk powder diet was the reference or control (Baskaran, Mahadevamma, Malleshi, Jayaprakashan, and Lokesh, 2001). The tenth diet was the protein free diet. The maintenance diet which comprised pure maize flour had a protein level 5.2% lower than the rest of the diets. This is because the protein content in maize was 9.48%.

All the experimental diets were prepared by incorporating the flours and milk powder into the protein free diet at the expense of the cornstarch-sucrose mixture of 1:1 ratio to obtain the required 1000 g by volume. The diets also provided 1% cellulose (bran), 5% mineral and 1% vitamin fortification mixes shown in Table (Table 3.2). A tenth, protein-free diet in which the corn-starch sucrose mixture replaced the test protein was also prepared. The purpose of the protein-free diet was to estimate the endogenous nitrogen excretion of the rats. The eleventh diet prepared was for rehabilitation with the aim of providing 20% protein for catch-up growth. In order to provide this level of proteins, finger millet flour which had the highest protein content among the study complementary foods was composited with soy flour at the ratio of 50: 50. The amount of composite flour for the diet was calculated using the formula:

$$20\% \text{ protein content} = \frac{3.2 \times 100}{\% \text{ N of sample}}$$

The other dietary constituents for the rehabilitation diet were calculated in a similar way as for the other experimental diets. The oil content in all the ten diets was adjusted to 9% using corn oil.

3.6.3 Animals and Housing

Forty weanling male Albino rats, four to six-week-old from the same colony, weighing 90-130 g were purchased from the University of Nairobi department of Biological Sciences. The animals were maintained following guidelines for the care and use of Laboratory animals (National Research Council, NRC, (2011).

The animals were housed individually in wire-bottomed cages to allow faecal matter to drop on a base tray. The rats had exactly 12 hours of light and 12 hours of darkness in a day. Temperature was maintained at 21- 25^0C while a humidifier was used to maintain the humidity between 40-70%. Figure 3.2 shows the cage used for the rat study.

Table 3.2: Formulation of Eleven Experimental Diets (g/kg)

	Diet Weighting										
Ingredients	**Maize**	**F. Millet**	**Cassava: Soy**	**Maize: Soy**	**Sorghum: Soy**	**F. Millet: Soy**	**Banana: Soy**	**P. Millet: Soy**	**Milk Powder**	**Protein Free**	**Rehab. Diet**
Flours											
Maize	840	0	0	0	0	0	0	0	0	0	0
F. Millet	0	807.7	0	0	0	0	0	0	0	0	404.55
Soy Flour	0	0	0	0	0	0	0	0	0	0	404.55
Composites											0
Cassava: Soy	0	0	669.30	0	0	0	0	0	0	0	0
Maize: Soy	0	0	0	582.38	0	0	0	0	0	0	0
Sorghum: Soy	0	0	0	0	544.40	0	0	0	0	0	0
F. Millet: Soy	0	0	0	0	0	497.54	0	0	0	0	0
Banana: Soy	0	0	0	0	0	0	690	0	0	0	0
P. Millet: Soy	0	0	0	0	0	0	0	548.38	0	0	0
Others											
Milk Powder	0	0	0	0	0	0	0	0	333.32	0	0
Corn Oil	90	90	90	90	90	90	90	90	90	90	90
Mineral Mix	50	50	50	50	50	50	50	50	50	50	50
Vitamin Mix	10	10	10	10	10	10	10	10	10	10	10
Bran	10	10	10	10	10	10	10	10	10	10	10
Corn Starch	0	16.15	85.35	128.81	147.80	171.23	75	145.81	253.34	420	15.45
Sucrose	0	16.15	85.35	128.81	147.80	171.23	75	145.81	253.34	420	15.45
TOTAL	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000

Milk powder (Miksi®, Promasidor Ltd, Nairobi, Kenya); Corn oil (Elianto®, BIDCO Oil Refineries Ltd, Thika, Kenya); Mineral mix and Vitamin mix (Amilyte®, Ultravetis East Africa Ltd., Nairobi, Kenya); Bran (Commercially available); Cornstarch (Zesta Corn Starch®, Trufoods Ltd, Nairobi, Kenya); Sucrose (Mumias White Sugar®, Mumias Sugar Co. Ltd, Mumias, Kenya

Figure 3.1: Albino Rat (Retrieved from Warren Photographic, 2014).

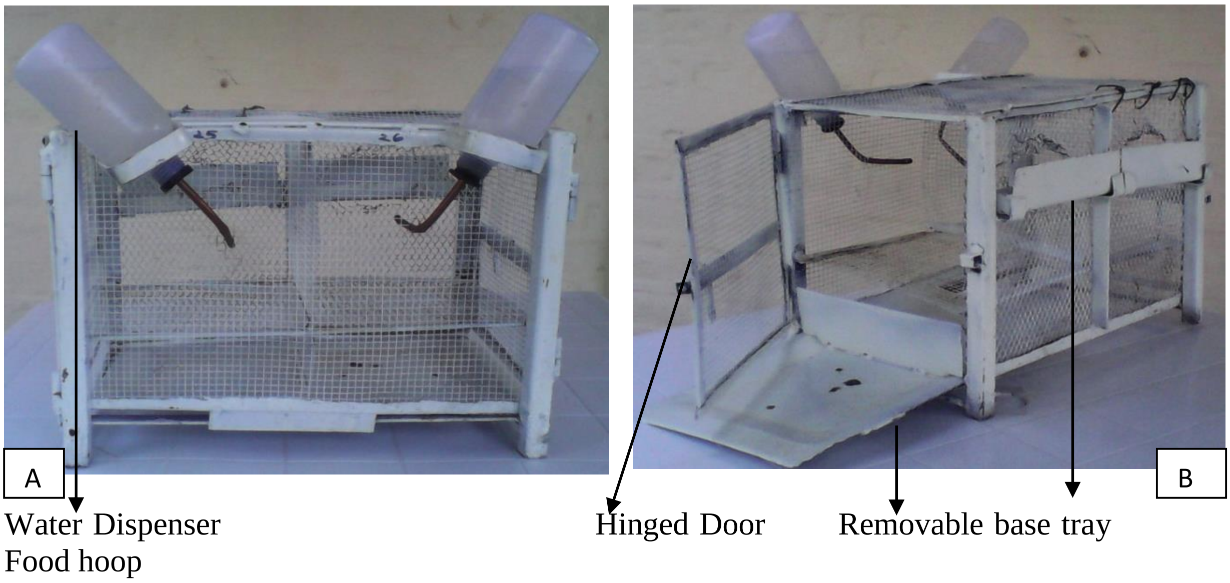

Figure 3.2: Housing used for rats in the study. A= Front view of rat cage; B= Side view of rat cage

3.6.4 Acclimatization

On arrival to the laboratory, the rats underwent an acclimatization period of three days (72hrs) (Boston University Research Compliance Committee, 2009) from 12th to 14th March. During acclimatization, they were fed on a standard pelleted diet (Hindustan Animal Feeds, Gujarat, India). From day 4 to day 6 (15th- to 17th March 2014), the rats were gradually introduced to the experimental diets by compositing the experimental diet with the rat pellets at a ratio of 1:1. After acclimatization on day 4, the rats were completely randomly distributed into ten treatments of four (4) rats (replicates) each.

3.6.5 Growth Study

Growth study lasted 28 days from day 7 to day 34 (18th March – 14th April 2014). Before the start of the experiment, the weight of the rats was taken using an electronic balance (Gebr. Bosch PE 625, Germany) and repeated on alternate days throughout the study. The first six groups were fed on cassava, maize, sorghum, finger millet, banana, and pearl millet flours fortified with soy at the ratio of 70:30. The seventh and eighth groups were fed on unfortified pure maize and finger millet diets, respectively. The ninth group was fed on two diets. First, the group was fed on the protein-free diet for 11 days. On the 12th day of the growth study, the protein-free diet was stopped and the rehabilitation diet began. The tenth group, the control, was fed on the skimmed milk powder diet. Each rat received 16 g of food per day. Water and food were available *ad libitum*. The data collected from this study was used in calculating the weight gained in the duration of the study which helped in the determination of the Food Efficiency Ratio (FER), NPR and PER.

3.6.6 Digestibility Study

The protein digestibility study lasted five days from day 7 – day 11 of the growth study (24th - 28th March 2014). During this period, records for the food given to each rat per day were maintained. The food remnants were also collected at the end of the day. The difference between food allowance and food remnants was used to calculate the food consumed per rat daily. The faecal material for each rat was collected daily into polyethylene bags and stored in a refrigerator.

3.6.7 Rehabilitation Study

The rehabilitation study lasted 17 days from day 12 to day 28 of the growth study (29th March – 14th April 2014). After the digestibility tests, the experimental group which had been fed on the protein-free diet lost weight. Since they could not be allowed to lose more than 20% of their body weight, they were put on a rehabilitation program. During this time, they continued receiving a daily food allowance of 16 g/rat/day from the finger millet: soy 50:50 ratio diet. The weights of the rats were taken on alternate days throughout the remaining period.

3.6.8 Chemical analyses

The faecal materials were pooled per group and sun-dried for 8 hours, then crashed using a mortar and pestle. The crude protein (N X 6.25) content of the faecal material was determined using the micro kjeldahl procedure (AOAC International, 1995) Method 984.13 (Chapter 3 – section 3.4.3). Faecal nitrogen from the rats fed the protein-free diet was used to calculate the endogenous nitrogen loss. True Protein Digestibility (TPD) was computed from nitrogen intake, faecal nitrogen and endogenous faecal nitrogen. Apparent Protein Digestibility (APD), Net Protein Retention Ratio (NPRR) and Protein Efficiency Ratio (PER), were also computed.

3.6.9.1 Computations

The data collected from the experiment was used in calculating the following protein quality indices using the formula suggested by FAO (2011):

$$\text{Protein Efficiency Ratio (PER)} = \frac{\text{g of weight gain}}{\text{g of protein consumed}}$$

$$\text{Net Protein Retention Ratio} = \frac{\text{g of weight gain + g of weight loss in protein free diet}}{\text{g of protein consumed}}$$

$$\text{Food Efficiency Ratio} = \frac{\text{g of weight gain}}{\text{g of food consumed}}$$

$$\text{Apparent Protein (N) Digestibility (\%)} = \frac{I - F \times 100}{I}$$

$$\text{True Protein (N) Digestibility (\%)} = \frac{I - (F - F_k) \times 100}{I}$$

$$\text{Fecal Protein (\%)} = \frac{F - F_k \times 100}{I}$$

Where I = Nitrogen Intake (calculated from the diet composition)
F = Fecal Nitrogen Output on the test diets
F_k = Fecal Nitrogen Output on a protein-free diet

3.6.9.2 Protein Digestibility Corrected Amino Acid Score (PDCAAS)

According to FAO (2011), (PDCAAS) is a method used in determining the protein quality of a food based on the requirement pattern for human beings. In this study, the amino acid scores for the 9 indispensable amino acids (histidine, leucine, isoleucine, lysine, methionine, tryptophan, phenylalanine, valine, and threonine) were calculated. These calculations were based on the requirement pattern for children aged 1 to 2 years.

$$\text{Amino acid score} = \frac{\text{mg of amino acid in 1 g test protein}}{\text{mg of amino acid in requirement pattern (1-2 year olds)}}$$

PDCAAS = True Protein Digestibility x Lysine score or limiting amino acid score (FAO, 2011).

3.7 Consumer Acceptability Tests

3.7.1 Porridge Sample preparation

Porridge for the evaluation was prepared as per the method outlined by Jacob (2008) with modifications on preparation of gruel for young children. The porridge contained

20% solids. For each of the six composite flours, about 750 ml of water was brought to the boil. In a mixing bowl, 100 g of flour was mixed with 150 ml water and made into a slurry. The mixture was added to the boiling water while continuously stirring. About 100 ml of water was added to bring out the desired thickness, making up 1000 ml of gruel. The gruel was allowed to simmer for 30 minutes on gentle heat and kept in vacuum flasks to keep warm before evaluation by the consumer panel.

3.7.2 Recruitment and screening

The test aimed at assessing the acceptability of porridge made from the soy fortified composite flours amongst the target population. Since children below 2 years of age who were the target population could not be used for the evaluation, parents were used as panelists because they make decisions on the type of foods eaten by the children. A sample of 50 parents was obtained from the University of Eldoret fraternity through an advert, telephone calls and email. The advert contained information on all the composite flours used in preparing the porridge. This information was meant to ensure those who signed up for inclusion were not allergic to soy or any other ingredient used in the porridge samples. Inclusion criterion was strictly based on being a parent with a child aged between 0.5 to 2 years.

3.7.3 Procedure for evaluation

Sensory evaluation of porridge samples was conducted at the Foods Laboratory of the Department of Family and Consumer Sciences of the University of Eldoret. A total of 50 panelists aged between 20 and 56 years (mean age 32.6 years) comprising 16 males and 34 females who were students or employees of the University of Eldoret participated in this study. Each panelist signed a consent form informing him/her of the nature of the samples they would evaluate before engaging in the sensory exercise. A total of seven (7) sessions lasting one hour each were carried out in one day using a completely randomized design as described by Lawless and Heymann (2010). Each panelist received a white tray containing the six samples of porridge in transparent glass bowls and a spoon for each sample. The trays also had a glass of deionized water to cleanse the pallet before and in between tasting different samples.

Each sample was labeled with three digit blinding codes and the samples were also randomized for each panelist. The panelists were seated back to back in the laboratory so that they could not see each other. Four sensory parameters of the gruel namely colour, taste, smell, and texture were used to determine consumer liking and overall acceptability were scored on a nine point hedonic scale (dislike extremely – 1: neither like nor dislike – 5 and like extremely – 9) for each sample (Peryam, & Pilgrim 1957). Responses to the evaluation were entered into a score card. Figure 3.3 shows the presentation of the six samples to the consumer panelists for tasting.

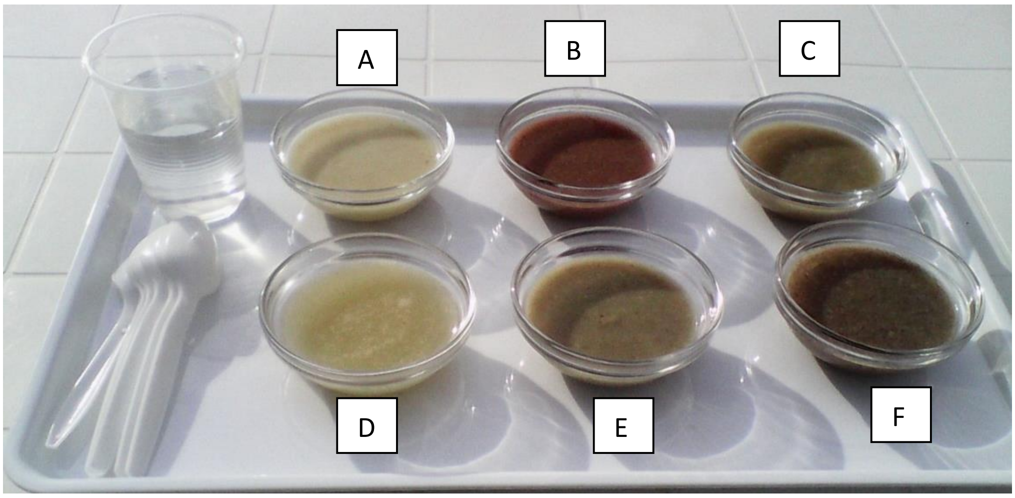

Figure 3.3: Tray set up for consumer evaluation. A= Maize: Soy; B= Sorghum: Soy; C= Banana: Soy; D= Cassava: Soy; E= Finger Millet: Soy; F= Pearl Millet: Soy

3.8 Ethical Considerations

Informed consent was used during the FGD and sensory evaluation panel where the respondents were informed on the purpose of the study and then asked for consent of participation. For the sensory evaluation, the consumers had to sign a consent form.

The feeding trials were carried out in compliance with the AOAC procedures regarding use of experimental animals and recommendations from the NRC. Ethical approval was also obtained from the National Commission for Science, Technology, and Innovation (NACOSTI).

3.9 Statistical Analyses

The preparation methods were analyzed through transcription of the recorded audio-visual discussions. All the chemical analyses were done three separate times in triplicates and presented as means and standard deviation. The chemical and rat growth data were subjected to one way analysis of variance (ANOVA) and means were separated using Least Significant Difference (LSD). The statistical software used was the Statistical Analysis System (SAS).

The consumer acceptability evaluation was not repeated. To test the effect of fortification on sensory attributes of porridges made from flours data were analyzed using Statistica Software Version 8.0 (Statsoft, Tulsa, USA). Fisher's Least Significant Difference Test (LSD) was used to separate the means. Box and Whisker Plots were used to demonstrate score distributions for total quality.

CHAPTER FOUR

RESULTS

4.1 Focus Groups Discussions

The responses obtained during the two FGD sessions in Bungoma and Busia are summarized in Table 4.1. The age range of the respondents was 32 to 52 years.

Table 4.1: Summary of Focus Groups Discussions in Bungoma and Busia Counties

Question	**Responses and Inferences**
At what age do you introduce other foods to your children apart from breast milk?	“After 6 months.” • This implies that the caregivers adhere to the IYCF recommended by WHO (2013) involving breastfeeding for the first 6 months of life.
What types of food do you give to these children?	“The children are given soft foods which are deemed easy to digest and nourishing for the baby. They include bananas, potatoes, and avocadoes. Thin porridge is also given.” • Choosing of children food is a process which needs the caregiver to be informed and sensitive on the needs of the children.
How often in a day are the children fed?	Bungoma: “The children are given 3 meals in a day.” Busia: “You cannot regulate the way a baby eats. At times the baby is asleep when you want to feed it, so you just have to feed the baby when it demands for food.” • IYCF practices are a bit varied in the two regions.
Which flours do you use to prepare children’s porridge, in order of popularity?	“Sorghum, pearl millet, cassava, groundnuts, *dagaa* fish (*Rastrineobola argentea*), and soy bean. Occasionally, finger millet is used when and if available.” Bungoma (on prompting whether maize is used): “No, maize is not used for children.” • Both FGDs agreed on the types of foods used except on maize which is used in Busia only.
Do you mix the flours?	“Yes.”

	- This indicates that compositing is a strategy used by the community.
If yes, which are the mixtures?	"There is no standard mixture because foods are chosen for inclusion into mixtures depending on availability and then all the chosen foods are mixed together. Some include sorghum and pearl millet which are mixed with groundnuts, *dagaa* fish (*R. argentea*), and beans if available." - Information on proper compositing of complementary foods needs to be disseminated.
How is the mixing done?	"Traditionally, the chosen foods are first washed and sun-dried. Some ingredients need special preparation. For instance, the head and tail of *dagaa* fish (*R. argentea*) is removed while groundnuts have to be picked. All the ingredients are then pooled together and milled. Most tubers and bananas (which don't need milling) are boiled and mashed together." - Mixing is done as per the popular culture where mothers or caregivers are advised by the experienced (older) generation on what should be done.
Briefly describe the process through which the porridge is prepared.	"Water is boiled in a cooking pan. A slurry is then prepared on a separate bowl using cold water. For the very young children, the slurry is passed through a sieve so as to reduce the particle sizes to enable ease of swallowing. This is added to the boiling water and stirred until properly mixed. This is then left to boil till it is well cooked (about 20±5 minutes). A little sugar is added." - There is a standard method for preparing the children's foods.
Would you like to know how soy can be added into the children's food?	"Yes." - This means that the people were willing to learn more ways that they can incorporate soy into the diet.

4.2 Effect of soy-fortification on proximate and mineral composition

Fortification with 30% soy meal resulted in an increase in protein, moisture, oil, and ash (mineral) contents, but a reduction of carbohydrates in all the complementary foods as shown in Table 4.2.

Protein content was highest 37.05 g/100 gin soy flour, the fortificant. Among the flours, finger millet had the highest protein content of 12.38 g/100 g while cassava had the lowest with 1.69 g/100 g. Complementation with soy increased the protein content with finger millet: soy composite having the highest protein content of 20.21g/100 g while the lowest value was in banana: soy with 14.59 g/ 100 g. All the fortified flours had significantly higher protein content compared to their respective unfortified flours (P<.0001). There were increases of 798%, 83.65%, 95.44%, 63.25%, 120.06% and 93.78% in cassava, maize, sorghum, finger millet, banana, and pearl millet soy composites, respectively, compared to their flours.

In comparison to all the foods, soy bean meal had the highest oil content of 19.33 g/ 100 g. Finger millet flour had the highest oil content among the flours, 7.33 g/100 g. Pearl millet and cassava which were lowest had values of 1.33 and 1.67 g/100 g, respectively. The oil content in the composites ranged from 9.50 g/100 g in pearl millet: soy to 11.33% in maize: soy flours. Therefore, fortification with soy increased the oil content by 479.04% in cassava: soy and 200.30% in sorghum: soy while maize soy had an increase of 161.66%. The lowest, increase of 22.78% was obtained in finger millet: soy while the highest was 614.29% in pearl millet: soy.

Table 4.2: The effect fortifying flours with 30% soy on proximate composition (g/100 g)

	Ash	**Moisture**	**Oil**	**Protein**	**Carbohydrate**[1]	**Energy(Kj)**[2]
Flours						
Cassava	$1.17^{hg}\pm0.01$	$9.67^{cb}\pm0.01$	$1.67^{ih}\pm0.01$	$1.69^{i}\pm0.08$	$85.82^{a}\pm0.94$	$1527.16^{fe}\pm3.62$
Maize	$0.83^{h}\pm0.01$	$10.17^{b}\pm0.01$	$4.33^{f}\pm0.01$	$9.48^{g}\pm0.62$	$75.19^{dc}\pm0.62$	$1580.16^{d}\pm10.32$
Sorghum	$1.33^{hg}\pm0.01$	$11.00^{a}\pm0.00$	$3.33^{g}\pm0.01$	$9.43^{g}\pm0.16$	$74.91^{d}\pm0.23$	$1536.92^{e}\pm9.43$
Finger Millet	$1.67^{g}\pm0.01$	$9.17^{cd}\pm0.01$	$7.33^{e}\pm0.01$	$12.38^{f}\pm0.34$	$69.45^{e}\pm0.62$	$1645.71^{b}\pm9.43$
Banana	$4.50^{e}\pm0.01$	$8.00^{e}\pm0.02$	$2.00^{h}\pm0.01$	$6.63^{h}\pm0.38$	$78.87^{b}\pm0.94$	$1506.24^{fg}\pm15.79$
Pearl Millet	$3.00^{f}\pm0.00$	$9.67^{cb}\pm0.01$	$1.33^{i}\pm0.01$	$9.32^{g}\pm0.40$	$76.67^{c}\pm0.87$	$1489.50^{g}\pm13.72$
Soy	$8.50^{a}\pm0.01$	$9.33^{c}\pm0.01$	$19.33^{a}\pm0.01$	$37.05^{a}\pm0.69$	$25.78^{i}\pm0.76$	$1779.59^{a}\pm7.35$
Composites						
Cassava + Soy	$5.50^{d}\pm0.12$	$8.50^{ed}\pm0.94$	$9.67^{c}\pm0.24$	$15.17^{e}\pm0.32$	$61.16^{f}\pm0.79$	$1641.52^{b}\pm18.28$
Maize + Soy	$5.50^{d}\pm0.24$	$9.33^{c}\pm0.59$	$11.33^{b}\pm0.59$	$17.41^{d}\pm0.34$	$56.42^{h}\pm0.85$	$1662.44^{b}\pm23.33$
Sorghum + Soy	$5.17^{ed}\pm0.47$	$9.17^{cd}\pm0.47$	$10.00^{c}\pm0.354$	$18.43^{c}\pm0.81$	$57.24^{hg}\pm0.49$	$1642.92^{b}\pm25.99$
F. Millet + Soy	$5.83^{cd}\pm0.59$	$9.00^{cd}\pm0.00$	$9.00^{d}\pm0.47$	$20.21^{b}\pm0.16$	$55.95^{h}\pm0.64$	$1613.63^{c}\pm21.16$
Banana + Soy	$6.67^{b}\pm0.00$	$10.17^{b}\pm0.47$	$9.83^{c}\pm0.47$	$14.59^{e}\pm0.13$	$58.75^{g}\pm0.43$	$1597.59^{dc}\pm9.43$
P. Millet + Soy	$6.5^{cb}\pm0.59$	$9.17^{c}\pm0.47$	$9.50^{dc}\pm0.00$	$18.06^{dc}\pm0.25$	$56.78^{h}\pm0.68$	$1610.14^{c}\pm23.14$

Values are Means ± standard deviation. Values with the same superscript letters on the same column are not significantly different at ($P<0.05$) as assessed by Least significant difference.

[1] Calculated using the difference method (FAO/WHO, 1998) where % carbohydrates = 100 – (% fat + % moisture + % ash (minerals) + % protein)

[2] Calculated by multiplying with Atwater's factor (FAO, 2012) where energy (Kj) = (%carbohydrates x 16.736) + (%protein x 16.736) + (%oil x 37.656

Table 4.3: The effect fortifying flours with 30% soy on mineral composition (mg/100 g)

Mineral	**Cassava: Soy**	**Maize: Soy**	**Sorghum: Soy**	**F. Millet: Soy**	**Banana: Soy**	**P. Millet: Soy**
Iron	1.00^{b}±0.36	0.62^{c}±0.03	0.59^{c}±0.02	1.82^{a}±0.03	0.63^{c}±0.07	0.54^{c}±0.04
Zinc	0.35^{a}±0.17	0.20^{c}±0.00	0.24^{bac}±0.03	0.34^{ba}±0.01	0.19^{c}±0.02	0.22^{bc}±0.02
Copper	0.10^{a}±0.03	0.06^{bc}±0.02	0.03^{c}±0.29	0.08^{ba}±0.00	0.04^{bc}±0.02	0.06^{bc}±0.01
Manganese	0.23^{c}±0.04	0.28^{cb}±0.01	0.31^{b}±0.01	0.31^{b}±0.01	0.24^{c}±0.05	1.27^{a}±0.05

Values are Means± standard deviation. Values with the same superscript letters on the same row are not significantly different ($P<0.05$) as assessed by LSD

The ash content, which represents the minerals in the complementary foods, also increased significantly in all the fortified flours compared to the non-fortified flours. There was an increase of 48.22% in banana: soy, 562.65% in maize: soy, 370% in cassava: soy, 288.72 in sorghum: soy, 249.10% in finger millet: soy and 116.67% in pearl millet: soy compared to their flours. Soy flour again had the highest (8.50 g/100 g) ash content. The banana: soy composite had significantly higher ash content (6.67 g/100 g) than all the other fortified flours except millet: soy with 6.5 g/100 g.

Moisture content in the composite flours decreased as a result of fortification. The decrease, however, was not significant for most of the foods. Banana flour had the lowest moisture content, (8 %) and the highest was sorghum flour with 11%.

There was a significant decrease in the carbohydrate content as a result of soy fortification by 28.73%, 24.96%, 23.59%, 19.44%, 25.51%, and 25.94% in cassava, maize, sorghum, finger millet, banana, and pearl millet, respectively. Cassava: soy had the highest carbohydrate content (61.16 g/100 g) and was significantly different from all the others foods.

As a result of fortification, cassava: soy, maize: soy, sorghum: soy, banana: soy, and pearl millet: soy had 7.49%, 5.21%, 6.90%, 6.06%, and 8.10% increases in energy content, respectively. These increments were significant ($P<.0001$). However, energy content in finger millet: soy decreased by 1.95%.

Results from the analysis of mineral content in soy fortified cassava, maize, sorghum, banana, finger millet, and pearl millet are shown in Table 4.3. Finger millet: soy had the highest iron content (1.82 mg/100 g), which was significantly different from all the other diets. Cassava: soy was also significantly different from the rest, having a value of 1.00 mg/100 g. All the other composites were statistically similar. Zinc content in cassava: soy (0.35 mg/100 g) was higher than the content in maize: soy, banana: soy, and pearl millet: soy.

The highest copper content was recorded in cassava: soy (0.10 mg/100 g) which was significantly higher than all the other diets with the exception of finger millet: soy. Pearl millet: soy had the highest manganese content (1.27 mg/100 g) which was statistically different from all the other diets. Sorghum: soy and finger millet: soy were statistically similar but both were significantly different from banana: soy and cassava: soy.

4.3 Effect of soy fortified complementary foods on growth and rehabilitation in rats

Various growth parameters were evaluated in the study and these are as reported in Table 4.4.

The PER for the complementary foods is shown in table 4.4. Banana-soy had the highest value (1.46), closely followed by the finger millet: soy (1.17). These two had PER values which were the same as the control protein (0.95). Sorghum-soy had the lowest PER amongst the fortified cereal-based diets (0.67). The cassava-soy diet also had low PER, being 73.68% lower than the milk powder protein. Of the maintenance diets, it was surprising that the finger millet had relatively high PER of 0.83, though lower than the corresponding fortified finger millet-soy diet by 29.06%. The 100%

maize diet, however, had the lowest value which was on the negative, close to zero (0) as shown in table 4.4. Cassava: soy, at 70.53% lower than milk powder, was also significantly different from all the other diets with the exception of sorghum soy. All the other diets were statistically similar to each other and to the control protein.

Table 4.4: Growth Indices for Rats Fed on Non-Fortified Flours and Soy-Fortified Composites

	PER	**NPRR**	**Weight Gain[1] (g)**	**Weight Gain[2] (g)**	**FER**
Flours					
Maize	-0.01^{d}±2.43	-1.09^{a}±2.64	-0.07^{c}±7.08	3.83^{c}±1.84	0.001^{dc}±0.24
Finger Millet	0.83^{ba}±2.28	-0.17^{a}±2.53	4.36^{ba}±4.34	22.36^{ba}±3.86	0.08^{ba}±0.23
Composites					
Cassava + Soy	0.25^{c}±0.52	-0.63^{a}±0.50	1.51^{cb}±2.89	13.03^{b}±1.55	0.03^{c}±0.05
Maize + Soy	0.90^{ba}±0.98	0.03^{a}±0.98	5.44^{ba}±5.32	27.52^{a}±11.99	0.09^{a}±0.09
Sorghum + Soy	0.67^{cba}±0.62	-0.22^{a}±0.69	3.94^{ba}±3.53	14.5^{b}±7.41	0.07^{ba}±0.06
Finger Millet + Soy	1.17^{a}±1.82	0.08^{a}±2.39	5.61^{ba}±5.94	24.61^{a}±17.59	0.12^{ba}±0.18
Banana + Soy	1.46^{a}±0.67	0.48^{a}±0.85	7.80^{a}±4.53	32.27^{a}±14.36	0.15^{a}±0.07
Pearl Millet + Soy	0.76^{ba}±2.09	-0.22^{a}±2.55	4.07^{ba}±8.14	13.68^{b}±5.91	0.07^{ba}±0.21
Protein Free	-	-	-5.24^{d}±1.47	26.61^{a}±10.78	-0.13^{d}±0.04
Milk Powder	0.95^{ba}±1.29	0.25^{a}±1.27	6.89^{a}±0.42	28.41^{a}±2.12	0.11^{ba}±0.13

Values are means± standard deviation. Values with the same superscript letters along the same column are not significantly different ($P<0.05$) as assessed by Least significant difference.

PER = Protein Efficiency Ratio
NPRR = Net Protein Retention Ratio
FER = Food Efficiency Ratio

[1] Weight gain during the digestibility test

[2] Weight gain after 28 days

Weight gain during the five day digestibility tests (Day 7-11 of the growth study) is as recorded in Table 4.6. Again, the banana-soy diet emerged superior, having a value (7.80 g) that was higher than even the control protein (6.89 g), though not statistically different (P = 0.3634). All the fortified diets were statistically similar to the control protein apart from the cassava-soy diet which came out inferior with a 78.08% lower weight gain as compared to the control. As expected, the group fed on protein free diet lost weight while the maintenance group on 100% maize meal having a value of very close to zero (0), indicating that there was neither loss nor gain in weight. The 100% finger millet, however, recorded increase in weight (4.36 g). These differences are further brought out in the NPRR where the banana had the highest value (0.48), being 47.92% higher than the control (0.25).

FER is also as shown in Table 4.4. The banana-soy and finger millet-soy diets were the highest with values 26.67% and 8.33% respectively, higher than the milk powder. All the fortified diets were comparable to the milk powder except for the cassava-soy which was 72.72% lower than the milk powder, a difference that was significant (P = 0.4899). The FER for the protein free diet was way below zero (-0.13) while the maintenance diet comprising of 100% maize meal had a value of 0.001, indicting no growth took place. The 100% finger millet diet, however, supported growth and was not statistically different from the milk powder.

The ultimate measure for growth was the weight gain after the 28 days of the growth study, (Table 4.4). The banana-soy diet was the best, with the rats in the group having a total weight gain of 32.27 g that was 11.96% higher than the milk powder. The animals on the milk powder diet gained 28.41 g in weight, closely followed by maize-soy at 27.52 g and finger millet-soy at 24.61 g. The cassava-soy, pearl millet-soy, and finger millet-soy were 54.14%, 51.85%, and 48.96%, respectively, lower than the control. Weight gain in the 100% maize meal maintenance diet was a meager 3.83 g which was significantly lower than the corresponding maize: soy diet. Surprisingly, the 100% finger millet maintenance diet supported growth, leading to a weight gain of 22.36 g which was higher than some of the fortified diets but not exceeding the corresponding finger millet-soy diet. Cassava: soy, pearl millet: soy and sorghum: soy diets were statistically similar to each other in supporting growth but significantly lower than the milk powder protein.

The animals fed on a protein free diet lost 8.78 g during the first 11 days of the growth study. From day 12, they were introduced to the rehabilitation diet and at the end of the study there was dramatic, 35.71 g weight gain (Figure 4.2). More detailed information on the growth study is represented in Figures 4.1 and 4.2.

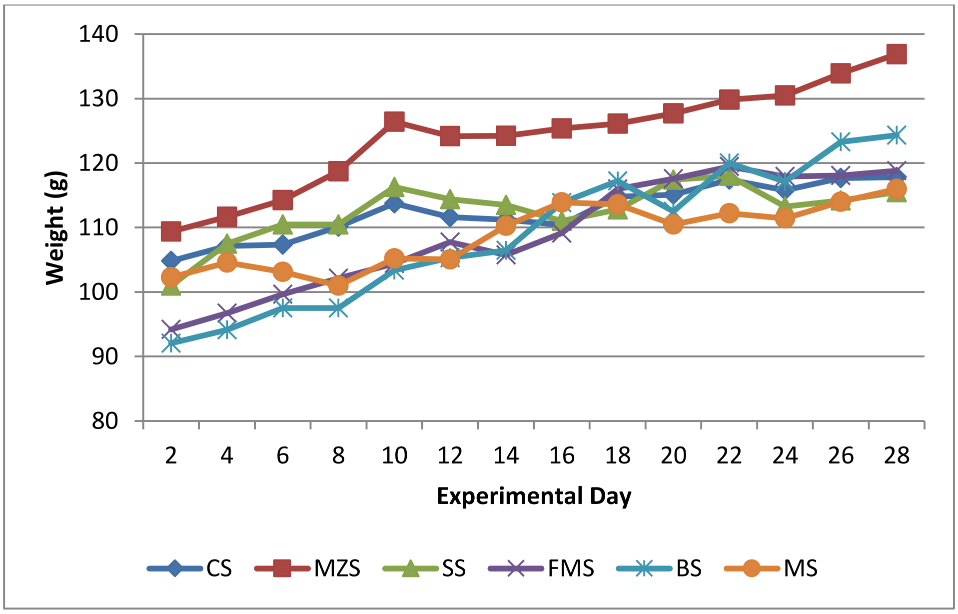

Figure 4.1: Mean weight of rats fed on the six soy fortified diets for a period of 28 days

Figure 4.1 shows that all the groups gained weight when fed on the fortified diets, just as seen in Table 4.4. From day 10 to day 15, the group on cassava-soy lost weight. They later regained weight and went on to the end of the study while on an upward trend but only gained 12.43% of the original body weight. The group fed on maize-soy steadily gained weight from day 1 to day 10 and then gained moderately to the end of the study with an impressive weight gain of 25.16%. Rats fed on the finger millet-soy diet steadily gained weight from day 1 to day 12. They slightly lost weight between day 13 and 14 but later continued with the weight gain to the end of the study. Total weight gain for this group was 26.13%. The group fed on banana-soy steadily gained weight from day 1 to day 18 when the growth fluctuated between day 19 and 24, and then stabilized to the end of the study to record the highest weight gain of a massive 35.05% of the original body weight. The growth in the rats fed on pearl millet-soy and sorghum-soy diets was quite intermittent and unstable as seen in Figure 4.1. The overall growth between the groups was also very similar (13.37% and 14.36%, respectively) as seen in Figure 4.1 and Table 4.4.

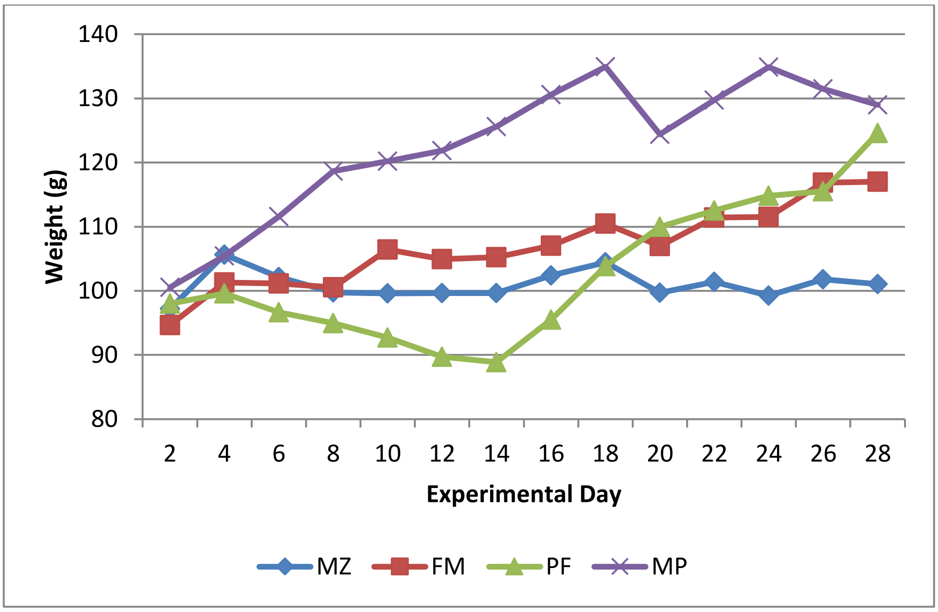

Figure 4.2: Growth of animals fed on maize, finger millet, pearl millet, milk powder, and protein free diet, showing rehabilitation feeding

From Figure 4.2, the rats fed on the control protein (skimmed milk powder) steadily gained weight from the first day of the study to day 18 when they reached the peak weight. The growth then became intermittent to the last day of the study characterized by sharp weight losses and gains. At the end of the study, the rats had gained 28.25% of their original weight. Rats fed on the maintenance diet comprising of 100% maize meal neither gained nor lost significant weight. They sharply gained weight for the first two days and then sharply lost weight between days 3 and 6. They maintained a constant weight from day 7 to day 12 and then started slightly gaining and loosing weight such that they maintained their body weight, gaining a meager 3.93% of their initial body weight. The rats on a maintenance diet made of 100% finger millet recorded gradual weight gain through the study to record a 23.62% weight gain.

The group fed on the protein free diet slightly gained weight for the first two days of the study. They then steadily lost weight from day 3 to day 11 during which 9.29% of their initial body weight was lost. After rehabilitation feeding was initiated on day 12 of the growth study, there was a dramatic weight gain from day 14 to the last day of the study with the group ending the study on a steady weight gain, having gained 28.25% of their original body weight and an impressive 45.10% on catch-up growth.

4.4 Protein nutritional quality of soy fortified composite flours

4.4.1 The protein digestibility study

Table 4.4 shows that protein intake, output and indices of protein quality for the ten diets. The food intake for the group of rats fed on the control diet was the highest followed by the finger millet: soy diet intake which was 26.67% lower than the control diet. The group of rats fed on the protein free diet consumed the smallest amount, which was 38.64% lower than the milk powder protein, and was also significantly lower (P = 0.1397) than all the other diets.

The protein intake from the diets fed to the ten groups of rats are shown in Table 4.5. There was no significant difference in the amount of protein ingested by the rats across the groups (P = 0.7875). However, the group fed on the milk powder had the highest intake of proteins (6.52 g) compared to the other 9.

Faecal bulk during the five days of the digestibility study varied among groups with the group fed on the protein free diet having the lowest volume (0.62 g). Of the isonitrogenous diets, milk powder had the lowest faecal weight of 2.28 g. Sorghum-soy had the highest faecal weight (5.33 g) which was 57.22% higher than the milk powder protein. Of all the fortified flours, only sorghum-soy, banana-soy, and pearl millet-soy were significantly higher than the milk powder protein with values that were 133.77%, 99.56%, and 92.54% higher, respectively.

Table 4.5: Effect of consumption of unfortified and soy fortified flours on protein intake, output, retention and protein quality Indices

	Food Intake (g)	**Protein Intake (g)**	**Faecal Output (g)**	**Protein Output[1] (g)**	**Protein Retention (g)**	**APD (%)**	**TPD (%)**
Flours							
Maize	50.72^{bac}±8.66	5.07^{a}±1.15	2.63^{c}±0.32	0.23^{e}±0.03	4.84^{ba}±0.12	97.57^{a}±7.76	98.72^{a}±2.94
Finger Millet	52.70^{bac}±9.97	5.27^{a}±1.68	3.89^{bac}±1.81	0.25^{e}±0.07	5.02^{ba}±0.62	96.54^{a}±6.67	97.61^{a}±3.24
Composites							
Cassava + Soy	59.43^{ba}±3.60	5.94^{a}±0.36	3.33^{bc}±0.85	0.74^{ba}±0.24	5.20^{ba}±0.40	93.05^{cba}±6.67	94.03^{dcb}±6.38
Maize + Soy	60.58^{ba}±4.68	6.06^{a}±0.47	3.87^{bac}±0.71	0.51^{dc}±0.11	5.55^{ba}±0.49	94.63^{ba}±4.46	95.59^{ba}±3.62
Sorghum + Soy	58.69^{ba}±6.49	5.87^{a}±0.65	5.33^{a}±1.07	0.78^{a}±0.07	5.09^{ba}±0.64	87.82^{c}±5.98	88.81^{d}±4.55
F. Millet + Soy	47.79^{bc}±7.02	4.78^{a}±1.80	3.24^{bc}±1.64	0.49^{bc}±0.27	4.27^{ba}±0.54	92.95^{cba}±3.82	94.14^{cb}±5.39
Banana + Soy	53.36^{bac}±4.78	5.34^{a}±1.02	4.55^{ba}±1.61	0.56^{bc}±0.13	4.78^{ba}±0.99	91.05^{c}±9.02	92.15^{dc}±6.62
P. Millet + Soy	53.51^{bac}±7.20	5.35^{a}±1.77	4.39^{ba}±1.37	0.39^{de}±0.12	4.96^{ba}±0.65	94.02^{ba}±3.21	95.07^{cba}±8.78
Protein Free	39.99^{c}±2.92	-	0.62^{d}±0.18	-	-	-	-
Milk Powder	65.17^{a}±1.66	65.17^{a}±1.66	2.28^{dc}±0.47	0.40^{de}±0.05	6.12^{a}±0.92	93.60^{ba}±3.73	96.27^{ba}±1.37

Values are means ± standard deviation.Values with the same superscript letters along the same column are not significantly different ($P<0.05$) as assessed by Least significant difference.

APD = Apparent protein Digestibility

TPD = True Protein Digestibility

[1] Faecal protein from the diet itself attained by subtracting the endogenous protein (in the protein free diet) from all the other diet

The protein output for the different diets is also indicated on Table 4.5. The values for the nine diets were obtained by subtracting the endogenous nitrogen excretion of the protein free diet from the total protein output of each diet. The maintenance diet comprising 100% maize flour had the lowest protein output (0.23 g) while sorghum-soy had the highest (0.78 g). Sorghum: soy had an output that was 95% higher than the milk powder. The protein output for the 100% maize meal and 100% finger millet meal maintenance diets was significantly lower than and different from the corresponding fortified diets (P <.0001) by 54.90% and 48.98%, respectively. The output for sorghum: soy (0.78 g) was higher than all the other diets except cassava: soy (0.74 g). Pearl millet: soy output (0.39 g) was significantly different from banana: soy (0.56 g) and finger millet: soy (0.49 g). Protein retention was similar across the diets but the control had the highest value (6.12 g), though this was not statistically significant.

The APD of the diets ranged from 87.82% in sorghum-soy to 97.57% in the maize diet. This denotes a difference of 11.10%. Of the fortified complementary flours, sorghum: soy (87.82%) and banana: soy (91.05%) were statistically similar but significantly different from the control protein.

The TPD of the diets is also indicated in Table 4.5. Maize meal had the highest value (98.72%) while sorghum had the lowest value (88.81%). There was a difference of 11.16% between the highest and the lowest values. Sorghum: soy and banana: soy (92.15%) were significantly different from the control protein (96.27%) and maize: soy (95.59%). Interestingly, the unfortified finger-millet diet had a significantly higher value (97.61%) than the soy-fortified finger millet diet (94.14%) as shown in Table 4.4. Generally, fortification with soy reduced the digestibility of flours.

To further assess the protein quality of the fortified foods in terms of ability to meet the protein nutritional requirements of 1-2 year old children, the PDCAAS was calculated as shown in Table 4.6.

Of the fortified flours, maize-soy valued highest (70%) while sorghum-soy was the lowest (56%). In comparison, the fortified diets had higher PDCAAS than the non-fortified diets. Maize: soy had a PDCAAS of 70% compared to 53% in pure maize meal which translates into a 32.08% increment as a result of fortification. Similarly, finger millet: soy had a PDCAAS of 64% compared to 46% in the non-fortified finger millet which shows that fortification led to a 39.13% rise in PDCAAS. Nevertheless, it was found that the maintenance diets had higher amino acid profiles than the fortified flours. Maize: soy had 432.26 mg/1000g protein against pure maize's 440.98 mg/1000 g while finger millet: soy had 464.04 mg/1000g compared to pure finger millet's 477.79 mg/1000g.

Table 4.6 also shows that cassava: soy is the only diet that does not fulfill the amino acid requirements for the children aged 1-2 years, falling short by 37.47%. Interestingly, the diet is not limiting in lysine and has a relatively high PDCAAS value when compared to the other diets. All the other diets meet the minimum amino acid requirements for children aged 1-2 years as recommended by FAO (2011) with finger millet: having the highest value. Another interesting fact is that the banana: soy diet is much superior to the cereal-based diets in the Lysine value. It also has a high amino acid profile and a PDCAAS value that is only second to maize: soy diet.

Table 4.6: Comparison of Essential Amino Acid Profile in Diets with FAO (2011) Requirement Patterns for Children aged 1 - 2 Years (g)

	Protein Sources									**FAO[2]**
[1]Amino acid	**Maize**	**F. Millet**	**Cassava: Soy**	**Maize: Soy**	**Sorghum: Soy**	**F. Millet: Soy**	**Banana: Soy**	**P. Millet: Soy**	**Milk Powder**	
Isoleucine	35.79	43.99	27.19	38.34	38.90	44.08	31.27	42.83	60.51	31
Leucine	122.66	142.98	42.40	108.18	112.42	122.41	66.00	111.25	97.95	63
Lysine	28.14	24.49	40.89	37.94	32.65	35.38	50.35	31.71	79.31	52
[3]Met + Cystein	38.96	46.24	28.19	35.38	33.85	40.48	19.03	35.62	34.32	26
[4]Phe + Tyrosine	89.75	93.12	46.8	87.49	79.99	89.85	61.91	83.10	69.58	46
Threonine	37.66	32.92	26.32	38.27	37.79	34.95	29.89	34.33	45.13	27
Tryptophan	7.07	15.82	13.76	8.93	12.79	15.06	9.77	11.54	14.10	7.4
Valine	50.50	54.32	31.70	49.03	45.79	57.71	43.87	50.40	66.92	42
Histidine	30.45	23.91	17.68	28.70	21.25	24.12	56.83	22.37	27.13	18
Total	440.98	477.79	274.93	432.26	415.43	464.04	368.92	423.15	494.95	312.4
TPD (%)	98.72	97.61	94.03	95.59	88.81	94.16	92.15	95.07	96.27	
Limiting AA	Lysine	Lysine	Leucine	Lysine	Lysine	Lysine	Met + Cys[5]	Lysine	None	
Limiting AA Score	0.54	0.47	0.67	0.73	0.63	0.68	0.73	0.61	1.53	
[6]PDCAAS (%)	53	46	63	70	56	64	67	0.58	100	

[1] Indispensable amino acid composition in foods is obtained from the USDA. (2013). *National Nutrient Database for Standard Reference Release 26*. The National Agricultural Library, 2013.

[2] Amino acid requirement pattern for children aged 1-2 years (FAO, 2011)

[3] Methionine

[4] Phenylalanine

[5] Cystein

[6] PDCAAS – protein digestibility corrected amino acid score

4.5. Acceptability of porridge prepared using soy fortified composite flours

Consumer Acceptability was assessed based on four characteristics; colour, aroma, taste, and texture. The values for these attributes are shown in Table 4.7.

Consumer liking for the sensory attributes of colour, smell, taste and texture for flours fortified with 30% soy are shown in Table 4.7. The colours for all the porridges were equally liked except for finger millet and cassava, which were significantly different from each other, with a higher liking for cassava. The smell and taste of the pearl millet, sorghum and cassava were perceived as better than maize, finger millet, and banana. Consumers liked the textures of all the porridges except the maize-soy composite.

All the types soy-fortified porridge were well accepted by the consumers on all the attributes. Taste was the least accepted at 5.83 while color was the most accepted attribute scoring 6.74 Colour was equally accepted between groups apart from cassava: soy (7.22) and finger millet: soy (6.30) whose acceptance was significantly different ($P<0.05$). For aroma, pearl millet: soy porridge was not different from all the rest at 6.64. Cassava: soy (6.52) and sorghum: soy (6.74) were equally accepted but significantly different from banana: soy (5.32), maize: soy (5.34) and finger millet: soy (5.14). Taste acceptance was similar and highest between cassava: soy (6.52) and sorghum soy (6.74) but significantly different from the other flours with the exception of pearl millet: soy which scored 5.92. Only cassava: soy and maize: soy had a significant difference in texture acceptance, each scoring 7.14 and 5.56, respectively.

Table 4.7: Consumer perception of sensory attributes for porridges from flour fortified with 30% soy meal

	Types of Soy Fortified Porridge						
Attribute	**Cassava**	**Maize**	**Sorghum**	**F. Millet**	**Banana**	**P. Millet**	**Overall Mean**
Colour	$7.22^{b}\pm2.14$	$6.50^{ab}\pm1.90$	$6.72^{ab}\pm2.52$	$6.30^{a}\pm1.90$	$7.08^{ab}\pm1.76$	$6.60^{ab}\pm2.16$	6.74±2.08
Aroma	$6.56^{b}\pm1.73$	$6.10^{a}\pm2.13$	$6.90^{a}\pm1.78$	$5.90^{a}\pm1.95$	$6.30^{a}\pm2.26$	$6.64^{ab}\pm1.78$	6.40±1.96
Taste	$6.52^{b}\pm1.95$	$5.34^{a}\pm2.37$	$6.74^{a}\pm2.28$	$5.14^{a}\pm2.64$	$5.32^{a}\pm2.27$	$5.92^{ab}\pm2.20$	5.83±2.36
Texture	$7.14^{b}\pm2.17$	$5.56^{a}\pm2.37$	$6.12^{ab}\pm2.44$	$6.72^{ab}\pm1.83$	$6.72^{ab}\pm1.99$	$6.48^{ab}\pm2.23$	6.46±2.22

Values are means± standard deviation. Values with the same superscript letters along the same row are not significantly different ($P<0.05$) as assessed by Fisher’s least significant difference

Total quality of attributes for the different types of soy-fortified porridge is as represented in Figure 4.3.

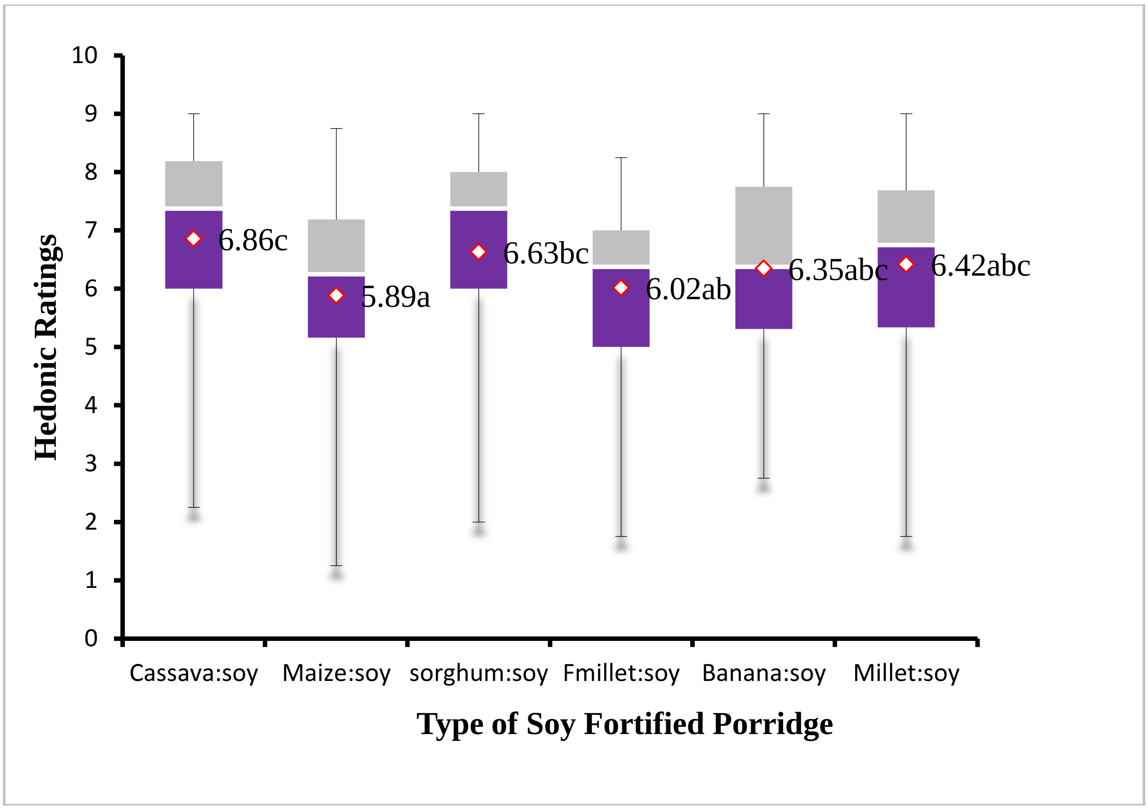

Figure 4.3: Consumer Acceptability of flours fortified with 30% soy meal by mothers and caregivers (n=50)

^{abc}= Mean values with different letter superscripts differ significantly at (P<0.05). The higher percentile is the lighter shaded area and the bottom represents the value above which 75% of the ratings fell. The lower percentile is the darker shaded area and the top represents the value above which 25% of the ratings fell. The border between the two shaded areas 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.

With reference to total quality, porridge made using the cassava: soy composite was the most accepted (Fig. 4.3) with a score of 6.86 while maize: soy was least accepted at 5.89 by consumers. Also there was a significant difference in consumer acceptability between the two flours with the cassava rated higher. The rest of the flours were considered equal in quality by consumers. The spread in the box and whisker plots shows that agreement among consumers was moderate as the lowest and highest score for each food are relatively far apart, although the score ranges between 1.25 and 9.

CHAPTER FIVE

DISCUSSION

5.1 Complementary Foods in Western Kenya

The findings from the FGD revealed that the parents and caregivers of children in Western Kenya do comply with the recommendations by the WHO (2007) that children aged 0-6 months should be exclusively breastfed and later introduced to complementary foods alongside breastfeeding. Complying with exclusive breast feeding may be a result of the wide health promotion carried out in the areas of study (United Nations Agency for International Development Infant and Young Child's Nutrition Project (USAID-IYCN, 2010) which encouraged participant to change or enabled them to contribute in terms of knowledge rather than practice. The findings in this study, however, contradict the report by Nyaga (2012) who also conducted a similar study and concluded that breastfeeding in Kenya starts at the age of 4-6 months.

The FGD also established that IYCF in Bungoma, the children are given three meals in a day. This is against the proper mode of introduction to complementary foods which recommends that a baby-led strategy should be adopted (Rai et al., 2007). This, however, could be explained by the high poverty levels in the rural areas in Western Kenya (KNDS, 2010) making the parents unable to afford the feeding requirements (Onofiok and Nnanyelugo, 2012).

The choice of foods the parents made for complementary feeding of young children in Bungoma and Busia were those that are normally available in these ecological zones. The findings also indicate that making of composites is a strategy that is used in the area. This shows that it is a strategy that can be exploited in dealing with the challenges associated with infants and young children diets in these regions. These results are consistent with the findings of Kinyuru et al (2012) where the starchy foods comprising grains, roots, and tubers were the most consumed. The *dagaa* fish (R. ergentea) was found to be the most common form of protein intake. It was also noted that in Bungoma, maize is not highly favored for complementary feeding. This could be attributed to the cultural belief that maize meal is not fit for young children.

The parents and caregivers also indicated that they incorporate soy into the children's diets. This could largely be due to the high popularization of soy in the region (AGRA, 2013). However, the challenge is that the soy is not well processed so as to reap maximum nutritional benefits. Only the sun-drying method is used, which is not effective in elimination of the anti-nutritional factors associated with soy (Riaz, 2012). This may be a problem because it could prevent the population from harnessing the maximum nutritional potential of the soybean. Nevertheless, the FGDs revealed that the people are keen to learn more on how to incorporate soy into the IYC diets. This is a channel that can be exploited in boosting the nutritional quality of the complementary foods, hence curbing the PEM menace.

5.2 Effect of soy-fortification on proximate and mineral composition

The proximate analysis affirmed that soy is nutritionally superior to most of the foods used in Western Kenya. This is consistent with the values for the nutrient composition of soy by USDA (2012). In this study, it was confirmed that soy had significantly ($P<.0001$) higher protein than all the other foods. The soy-fortified diets had higher protein content than the non-fortified diets. The lowest increment was in finger millet:

soy (63.25%) whereas cassava: soy had a dramatic increment of 797.63% (Table 4.2). This increment may be accounted for by the protein boost which accompanied the introduction of soy. This protein boost also made the fortified complementary foods meet the minimum protein content threshold recommended for complementary foods which is 15 g/100 g (Dewey, 2013). All the non-fortified flours were below this mark, but when fortified with soy, all exceeded the threshold but for the banana which fell short by a meager 0.41%. Further, 100 g of the soy-fortified complementary foods can meet the daily protein needs (13 g) for a child aged 1-3 years (WHO, 2013), a level that cannot be met by the non-fortified flours.

These findings are consistent with studies carried out by other workers. For example, a study carried out in Nigeria to determine the nutritional and sensory attributes of soy-supplemented cereal meals by Alabi and Anuonye (2007), found that fortification of wheat flour with soy flour in a ratio of 3:1, increased protein content by 100%. A similar study by Mariam (2005) to determine the nutritive value of commonly used cereal and legume based complementary foods established that the soy-fortified diet had a protein content 56.22% higher than the non-fortified diet. Furthermore, a diet that contained yellow maize: soy: groundnuts in the ratio 60: 30: 10 exceeded the protein RDA for the children aged 1-3 years (Mariam, 2005). These findings are consistent with the current study. These studies confirm that legume-fortification is an effective strategy in alleviating PEM.

The results in this study also established that soy had the highest oil content of all the foods. This can be explained by the fact that soy, being a legume, does not store its energy in the form of carbohydrate but has it concentrated as oil (USDA, 2012). It also explains why on fortification with soy, all the complementary foods recorded a significant increase in oil content. The findings from this study confirm the conclusion by Glover-Amengor, Quansah, and Peget (2013) who carried out a study to assess the performance and acceptability of legume-fortified yam flours in Ghana. The study showed that fortification of yams with soy, which is oil rich, yielded a composite with 143.01% higher oil content than non-fortified yams. This increment is within the range increment recorded in the current study (ranging from 22.78% in finger millet: soy to 614.29% in pearl millet: soy), affirming that indeed, soy-fortification increases the oil content in complementary foods. Oil is important in children's diet because it provides the energy needed for the increased physical activity in children (AGNHM, 2014). Additionally, children have small stomachs and cannot consume the large amounts of food required to meet their energy needs (Burgess and Glasauer, 2004). Oil, is a concentrated source of energy and 1 g provides 17 kJ increasing energy density while reducing bulk in children's diets.

The proximate analysis confirmed that soy has high ash content as established by USDA (2012). Its addition to the complementary foods, therefore, explains the notable higher ash content in the fortified than the non-fortified complementary foods. Similar findings were reported by Aremu et al (2011) in a study which established that fortification of maize ogi with kerstiengella groundnuts seeds, which are rich in minerals, increased the ash content of ogi. Another study by Mosha and Vicent (2004) tested the nutritional value of legume-fortified maize/sorghum-based weaning mixtures, and found that complementation resulted in higher ash content. Based on these findings, it is likely that using soy-fortified complementary foods can alleviate hidden hunger or micro-nutrient malnutrition (MNM) in children aged 1-2 years, a condition that is highly prevalent in developing countries (Allen et al., 2006). Ash content in a food represents the mineral content of the food.

Mineral content increased on fortification with soy. A similar conclusion was reached by Mosha and Vicent (2004) who found out that fortification increased mineral content in foods. However, 100 g of the soy-fortified diets fall short of the RDAs for the analyzed minerals; iron, zinc, manganese, and copper. This implies that other mineral sources, such as the green-leafy vegetables which are also widely used in Western Kenya (Kinyuru et al., 2012), should be incorporated in the diets. It also implies that the non-fortified complementary foods, which have significantly lower ash content than the fortified foods, would predispose the children to both PEM and MNM as confirmed by Dewey (2013).

Fortification with soy reduced the carbohydrate content in all the flours. This may be explained by the replacement with 30% soy in the composite flours when soy had the lowest carbohydrate content (25.78 g/100 g). The decrease in carbohydrate on addition of soy to starchy foods was also reported by Alabi and Anuonye (2007) who found that addition of soy to yams led to lower carbohydrate content. Carbohydrate is the main source of energy in the body with an RDA for children aged 1-3 years at 95 g/day (WHO, 2013). 100 g of the soy-fortified diets would provide between 55.95% and 61.16% of these children’s RDA.

Soy-fortification of the complementary foods increased the energy content in all other foods except finger millet. This increase could be attributed to replacement of the carbohydrates in the non-fortified foods with the energy dense oil and higher protein content in the fortified foods. Other studies have yielded similar results. For instance, in a study by Glover-Amengor et al (2013), soy-fortified yam flour yielded a 0.37% increase in energy content. This marginal increase in energy was also reported by Bakusuba and Nampala (2008) in a study in Uganda that assessed the nutritional density and quality of banana-soy based complementary foods. The researchers found that though soy-fortification produced a noticeable increase in other nutrients, especially protein, the increase in energy levels remained marginal or unnoticeable.

There was a decrease in energy on fortification of finger millet. This could be explained by the fact that finger millet is nutrient dense as indicated in Table 4.2. When fortified with soy, the protein and oil content increased but not by a large margin as in the other composites. This, coupled with the decrease in carbohydrate content, could have resulted in the decrease in energy content. The energy RDA for children aged 1-3 years is about 4142.2 kJ/day (FAO/WHO, 1998). 100 g of the soy-fortified foods would provide 38.57 – 40.13% of the children’s daily needs. If the children take at least 3 meals in a day, then their energy needs would be met. This conclusion was also reached by Mariam (2005) who established that 100 g of the soy-fortified complementary foods would not meet the nutrient needs of children. However, if the IYCF guidelines by UNICEF (2013) are adhered to and the children take at least 3 meals in a day, the energy requirements would be met, implying that the children would not be deficient.

5.3 Effect of soy fortified complementary foods on growth and rehabilitation in rats

PER is one of the commonly used methods of assessing the quality of a protein (FAO, 1981). A food with a higher PER is deemed superior to a food that yields a lower

PER. The significant difference in PER between the reference protein and cassava: soy diet (Table 4.4) could have been a function of anti-nutritional factors in cassava and soy which hindered effective utilization of the proteins, a conclusion supported by Nassar and Sousa (2007). As expected, low PER was recorded in the basal diet because it had no protein content. The fortified diets emerged superior to the non-fortified diets as seen by the very low PER in maize meal. This confirms the findings by Joseph and Swanson (1993) who established that cereal and legume combinations have superior protein quality compared to the individual legumes or cereals. However, it was interesting to note that pure finger millet had a PER similar to the reference protein. This is possibly as a result of the high protein content in the finger millet as seen in Table 4.2 (chapter 4). Stabursvik and Heide (1974) also came to a similar conclusion after assessing the nutrient composition in finger millet. It is, therefore, possible that a composite of soy and finger millet would provide variation that would be superior to milk protein as justified by the higher PER.

The banana: soy and finger millet-soy diets had higher PERs than the reference protein. This is despite the fact that the protein intake for the reference protein was higher. This is probably due to compositing cereals with legumes which yield high protein quality through complementation (FAO, 2002). It may also be attributed to the fact that the current study used milk powder as the reference protein like Baskaran et al (2001) with 33% protein instead of casein which has high protein content of above 90% (Rutherford and Maughan, 1998). The banana-soy diet, despite having the lowest protein content as seen in Table 4.2, yielded the highest PER of all the diets. Reduced amount of phytic acid and other anti nutritional factors to complex with the protein and other nutrients could explain the better outcome from the banana-soy diet. A similar study carried out by Bukusuba, Isabiry, and Nampala (2008) using soy-fortified banana and sesame revealed that a diet with lesser crude protein could yield better results than a diet with higher protein content, based on the quality of the protein. Banana, being a starchy fruit, is also free of phytates such as those found in cereals (Aremu et al., 2011) making most of the protein bioavailable.

The FER shows the ability of a food to support growth. The cassava-soy diet had a much lower FER than the milk powder. This is possibly due to the lower protein content and quality in cassava as noted by Nassar and Sousa (2007). Maintenance diet containing 100% maize was also significantly lower than all the other diets, owing to the fact that the protein content was not enough to support growth. Mosha and Bennink (2004) made a similar conclusion following a study in which corn meal led to an FER of 0.003. The banana-soy diet yielded the highest value, a finding similar to Bukusuba et al (2008) who attributed it to higher quality of proteins in banana-soy composite. Table 4.6 (Chapter 4) shows that the banana-soy diet had a better amino acid profile than all the other diets. Bananas are specifically high in lysine, an amino acid that is limiting in all the cereal-based diets (USDA, 2012). This is further supported by the overall higher growth of animals fed the banana-soy diet.

Growth rate was highest in the banana-soy diet. This may be attributed to the high amino acid profile (Table 4.6). This finding is supported by FAO (2002) that lesser protein of higher PDCAAS is better than higher quantity protein with lower PDCAAS at supporting growth. Bukusuba et al (2008) also concluded that soy-fortified banana has better protein quality. The growth rate in the banana-soy, maize-soy, and finger millet-soy, were similar to the reference. Cassava-soy, sorghum-soy, and pearl millet-soy diets were significantly different from the reference and also from the other diets. This can be explained by the lower protein quality in the diets (Table 4.6) which indicates that even though these diets supported growth, they could not be equated with the reference in ensuring nourishment of the young children. The results in this study imply that if the fortified flours supported growth in rats, which have higher amino acid requirement than children, the growth patterns observed in this study could be extrapolated to 1-2 year old children who consume foods made using the fortified flours.

5.4 Protein nutritional quality of soy fortified composite flours

The rat group consuming the protein-free diet had the lowest food intake, while the ones on milk powder and soy fortified flours were much higher. The quality and type of protein in a diet can influence food intake (Onofiok and Nnanyelugo, 2012). Food intake is determined by the body requirements as well as the ability of the foods to satisfy these needs. The protein in the body is needed for growth and development of body tissues (FAO, 2007). The difference between the other diets and the basal (protein free) diet with reference to food intake and protein intake could be attributed to the fact that the protein free diet did not meet the nutrient requirements of the rats and so it was shunned by the animals. A study carried out in South Africa by Serrem et al (2011) testing the digestibility of soy-fortified sorghum biscuits revealed that food intake and protein intake was similar for the reference protein (casein), the 100% sorghum flour and the sorghum: soy flour but all these were different from the basal diet. The low protein intake for the basal diet can be explained by the low protein diets which have been known to result in reduced food intake causing protein deficiency, emaciation, and death NRC (2011). It is possible that higher intake in the protein containing diets could be a result of improved flavour of the foods due to the presence of aromatic amino acids such as histidine, phenylalanine, tryptophan, and tyrosine, thereby encouraging intake (Hui, 2006). A similar study carried out in India also showed that food intake and protein intake for fortified and unfortified foods were similar but higher than the basal diet (Baskaran et al., 1999). This is also an indication that protein quality of fortified foods can only be tested using other indices of protein quality but not the intake.

Sorghum: soy and pearl millet: soy diets had the highest output of faecal volume. High faecal output is an indicator of reduced digestibility. It is possible that the presence of phytates, tannins and soy anti-nutritional factors complexed with nutrients and reduced their digestibility (Aremu et al., 2011). A study by Serrem et al (2011) revealed that the sorghum proteins, kaffirins, which are less digestible made the sorghum diet have a 57.14% higher faecal protein than casein. The high faecal output in banana: soy diet, similarly, could have resulted from the low digestibility of the diet (Table 4.5). Nevertheless, the digestibility level is higher than the range of legume containing diets (79-85%) (Sarwar, Peace, Botting, and Brule, 1989). Therefore, this lower digestibility probably did not have a negative effect on the protein quality in the banana: soy diet as seen in the higher growth rate seen in Figure 4.1 and higher amino acid profile (Table 4.6). This is in agreement with the conclusion by Bukusuba et al (2008) that soy-fortified bananas have good protein quality.

The soy-fortified diets had higher nitrogen excretion compared to the reference protein. It was also notable that the faecal nitrogen of the maintenance diets was lower than that of the fortified diets. This could be explained by the fact that the cereals have lower protein content (FAO, 2002). Therefore, individuals feeding on such diets would have to retain as much of the proteins as possible. This could also be due to the fact that legumes might support microbial activities in the digestive tract. A study by Wu et al (1995) to test the digestibility of kidney beans indicated that the protein output was as high as 43.8% for the unprocessed beans and 25.6 to 36% in processed beans. This was attributed to high microbial activity in the intestines which utilized the indigestible carbohydrates and protein from beans as the substrates. Onofiok and Nnanyelugo (2012) further found that many parents avoid feeding beans to their children for fear of poor protein utilization. Though the protein output in the soy-fortified diets in the current study was higher than the non-fortified diets, it is worth noting that the output was lower (7.35 – 13.39%) compared to the output recorded by Wu et al (1995). This could mean that soy-bean is a good choice for fortification of complementary foods.

The digestibility of the soy containing complementary foods ranged from 88.81% to 95.59% indicating that the unfortified diets had higher digestibility compared to the soy-fortified diets. This difference could have been brought about by lower digestibility of the soy-beans. Other workers have come to the same conclusion as evidenced by a study by Sarwar et al (1989) which investigated the PDCAAS of proteins with inhibitory factors. The study established that the range of digestibility for foods containing beans is 70-85%. Mosha and Bennink (2004) also found out that complementary foods fortified with beans and sardines had a digestibility ranging from 82 to 94%, a figure that is consistent with the findings of the current study. This shows that soy-fortified diets have lower digestibility than the non-fortified diets, though the former have protein of higher quality than the latter, making it the best choice for complementary feeding.

The non-fortified maintenance diets performed dismally in PDCAAS (53% for maize meal compared to 70% for maize: soy and 46% for finger millet compared to 64% of finger millet: soy diet). Soy fortification also resulted in an increase in indispensable amino acids, isoleucine, leucine, lysine, tryptophan, threonine, and valine in maize. Finger millet, once fortified, also had an increase in lysine, threonine, isoleucine, and valine. Kure and Wyasu (2013) also found out that after fortifying sorghum with soy, there was an increase in levels of lysine, methionine, and tryptophan. This confirms that soy fortification increases the protein quality of the complementary foods through complementation of the amino acids.

The quality of proteins is very important in supporting the growth of infants and young children (FAO, 2007). It is best determined by use of PDCAAS (FAO, 1991). The Codex Alimentarius Commission has put the threshold for PDCAAS for complementary foods at 70% and above. Of the soy-fortified diets used in this study, only maize-soy diet reached this threshold, with banana-soy, finger millet-soy, and cassava-soy diets missing the mark by very small margins of 4.29%, 8.57%, and 10%. Pearl millet-soy and sorghum-soy came short due to the limiting lysine content (Table 4.6). The soy-fortified diets in the current study showed the ability to support growth and rehabilitation. All except maize-soy came slightly short of the PDCAAS threshold, an indication that composites of the complementary flours and soy but with higher than the 70:30 ratio used in this study can help in preventing and managing cases of PEM. This is as seen in Figure 4.2 where a composite of finger millet-soy in the ratio 50:50 manifested dramatic recovery from wasting. Serrem et al (2011) also found out that a complementation of soy and sorghum in the ratio of 50:50 could yield a PDCAAS that meets the threshold for young children aged 1-2 years and 3-10 years. The cassava: soy diet, albeit having a relatively high PDCAAS, does not satisfy the amino acid requirements for children aged 1-2 years. A complementary food containing cassava as the base as well as pure cereal diets might not be recommended for complementary feeding since they have low PDCAAS.

5.5 Consumer Acceptability of soy fortified complementary foods

Consumer acceptability of new products is vital in ensuring their success (IFT, 1981). Porridge which is commonly fed to 1-2 year olds during weaning was used to establish if the fortified flours were acceptable for consumption. All the porridge types were well accepted by the consumer panel. This is possibly due to consumer familiarity because ingredients used were locally available to the consumers (Section 3.1). As such, the consumers were already familiar with the products. Similar findings have been reported by other workers. Mosha and Vicent (2004) found that developing new formulations of complementary foods using ingredients that are commonly used at homes results in higher acceptability of the products. Kure and Wyasu (2013) also confirm that consumers were more likely to accept foods that they are familiar with even when the foods are taken through different processes.

The sensory attribute of taste was the least liked by consumers in all the soy fortified porridges. The relatively lower acceptability of taste may be attributed to the beany flavor of the soy beans. The beany flavour which discourages consumption of soy beans has been attributed to the enzymatic breakdown of lipoxygenases (Boge, Boylston, and Wilson, 2009). It is possible that the consumers were not familiar with this flavour in their porridge. Similar conclusions were reached by Bukusuba et al (2008) in a study to asses the acceptability of porridge prepared using bananas, soy, and sesame. The cooked flavor of soy-beans was less liked by the consumers. Another possible reason is that there were flavours or additives such as sugar that were added to the porridge. Acceptability studies by Mosha and Vicent (2005) using corn, peanuts, sardines, and beans showed that consumers accept porridge that has flavourings. As such, it is possible that acceptability of the soy-fortified porridges could have been higher had other flavours been used to camouflage the beany flavor. Glover-Amengor et al (2013) also affirmed that porridge fortified with bean flour tends to be less accepted due to the beany flavor.

There were differences in the liking of colour between cassava: soy and finger millet: soy. Such differences may be associated to familiarity of consumers to the foods. Most of the consumers do not use finger millet (Table 4.1) but always use cassava, leading to higher liking of cassava than finger millet. The same case applies to the differences in acceptability of taste and smell for cassava: soy and sorghum: soy which were highly accepted in contrast to banana: soy and finger millet: soy which were least accepted (Table 4.7). The bananas in this study were also prepared differently. While most of the consumers boil and mash the green bananas for their children (Table 4.1), this study adopted a different style, making flour then porridge as described in Section 3.3.1. This could have affected the acceptability. Other studies carried out in banana growing and consuming areas confirm that consumers have their conventional ways of preparing the bananas. In a study to assess the proximate composition and consumption of bananas in Nigeria, Odenigbo et al (2013) established that fried bananas were most preferred at 73% acceptance level while boiled bananas came second at 66.7%. This study further reported that only 26.7% preferred bananas cooked in combination with other foods, which explains the low acceptability of the composites. Similar findings were also reported by Ekesa et al (2012) in a study to determine cultivar acceptance for bananas grown in Eastern Congo, concluding that over 69% of the banana-consuming households preferred them boiled. The main accompaniments for the bananas were beans and amaranth leaves (Ekesa et al., 2012). Findings from these studies indicate that bananas are either boiled or fried, but not dried and milled into flour. As such, they confirm the findings of the current study that banana flour composite was not highly preferred.

With regard to total quality, finger millet: soy and maize: soy were equally accepted but differed significantly with cassava: soy. A possible reason for the lower popularity of finger millet could be its reduced usage (Table 4.1). Maize: soy could have been rated lower than cassava: soy for two reasons. First, cassava: soy had a smooth texture as compared to maize: soy. Further, it is notable that the greatest variation between the latter and the former was reported in texture. Given that the evaluators were people who had young children in their subconscious when doing the evaluation, the possible rough texture in maize could have affected the outcome. Secondly, Table 4.1 indicates that in Bungoma, maize meal was not highly preferred for the children. However, it is contrary to the position taken by Nyaga (2012) that maize meal is one of the commonly used complementary foods in Kenya. Nevertheless, in a review, Nicklaus (2011) reports that children are offered the foods that are most preferred by their parents, implying that maize was less liked because though familiar, it is not preferred as a complementary food.

5.6 General Discussions

Low nutrient density is among the main challenges of infant diets in developing countries (Dewey, 2013). Protein deficiency is the main challenge in areas in which starchy foods and cereals are a staple. Western Kenya is one of such areas as indicated by the high PEM rates in the region (Nungo et al., 2012). This study established that fortification of complementary foods from Western Kenya with soy, which is locally available, can help alleviate PEM. Other studies on cereal complementation with legumes have yielded similar results. Serrem et al (2011) concluded that soy fortified sorghum had the ability to control PEM as did Bukusuba et al (2008) who made a similar conclusion on soy-fortified bananas. Mosha and Bennink (2004) also established that the complementation of beans with legumes is good at supporting growth. All these studies showed that protein quality and growth indices of the fortified foods were comparable to those of casein, the reference protein. This is unlike the current study which used milk powder as the control protein owing to unavailability of casein. Use of milk powder as control was also employed by Baskaran et al (2001), indicating that in the absence of casein, milk powder can be used as an alternative control protein though it has lower protein content (37%) compared to casein (90%).

There were two limitations in this study. First, there are several protein sources from Western Kenya that can be used for fortification such as the *dagaa* fish (*R. ergentea*) and other varieties of beans. However, this study only used soy bean because of its higher protein content compared to the other legumes (USDA, 2012) and its availability in higher amounts than *dagaa* fish (*R. ergentea*) since most of the residents are farmers. Secondly, soy can be used in fortification of diets for the entire household but in this study it was used in fortifying infants and young children's foods. This is because PEM, a condition that mainly affects children, is prevalent in Western Kenya. It is, therefore, important to curb the problem right from the onset.

Generally, the current study established that soy-fortified complementary foods from Western Kenya can aid in prevention and management of PEM as shown in the growth and rehabilitation studies. Furthermore, these foods are prepared from locally available materials, making them affordable as compared to the commercial complementary foods. This comparison is as shown in Table 5.1.

Table 5.1: Comparison of the costs of the composites with the cost of commercial complementary flour

	Cost (Ksh.)/Kg			
Complementary Flours	**Cereals**	**Milling**	**Total**	**Difference[1]**
Cassava: soy	73	10	83	37
Maize: soy	52	10	62	58
Sorghum: soy	73	10	83	37
Finger millet: soy	73	10	83	37
Banana: soy	98	10	108	12
Pearl millet: soy	73	10	83	37
[2]Winnie's Toto Afya	-	-	120	0

[1]Value obtained by subtracting the total cost of the composites from the cost of commercial complementary flour

[2]Comercially available complementary flour, Winnie's Pure Health®, Nairobi, Kenya.

From Table 5.1, it is evident that in case the consumer has to purchase the ingredients and make the composites at home, it would save from 10 – 48.33% on the cost of the commercially available complementary flour. However, it is worth noting that most of the target consumers would have most of the ingredients as they are locally available, thereby lowering the cost to just the milling price. This implies that using the composites is a very affordable way of curbing PEM and MNM.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

i. Fortification of complementary foods with 30% soy meal increases their nutrient density in terms of protein, fat, and mineral composition hence have the potential to alleviate Protein Energy Malnutrition in 1-2 year old children.

ii. Compositing complementary foods with soy decreases the protein nutritional quality index of digestibility (APD) and (TPD) but increases the PDCAAS value increasing their ability to satisfy the amino acid reference pattern for children aged 1 – 2 years.

iii. Thirty percent soy fortified complementary foods have a PER similar to the milk powder control and at 50% can rehabilitate malnourished rats. It appears that by extrapolation, fortified complementary foods can support growth, and rehabilitate malnourished children.

iv. Porridge made from soy-fortified flours is highly acceptable to mothers and caregivers of young children and has the potential to be adopted by them for use in young child feeding.

6.2 Recommendations

i. Banana-soy and maize-soy composited at 30% level should be used should be used for complementary feeding in Western Kenya. The high protein quality in these foods can help in alleviating PEM in the region.

ii. More studies that are similar should be carried out using different formulation levels so as to determine the optimum soy-fortification level. This is a level that can meet the minimum PDCAAS level recommended by the Codex Alimentarius Commission without adversely altering the organoleptic and other physico-chemical properties of the complementary food used as the fortification vehicle.

iii. Future studies should be carried out using cooked soy-fortified flours. The current findings were attained using raw flour. However, when the flours are subjected to cooking, the protein could undergo some changes which might affect their digestibility and availability. This forms basis for further investigations.

REFERENCES

AGRA. (2013). *Legume Cultivation Booms in Western Kenya*. Retrieved on 5th Sept. 2013 from http://www.agra.org/what-we-do/legume-cultivation-booms-in-western-kenya/

Alabi, M.O., & Anuonye, J.C. (2007). Nutritional and Sensory Attributes of Soy-Supplemented Cereal Meals. *Nigerian Food Journal*, Vol. 25(1), pp. 100-110.

Allen, L., de Benoist, B., Dary, O., & Hurrell, R. (2006).*Guidelines on Food Fortification with Micronutrients.* WHO and FAO, 2006.

A.O.A.C. (1995). *Official Method of Analysis Association of Official and Analytical Chemists*. Washington, DC, 12th Edition.

Aremu, M.O., Osifade, B.G., Basu, S.K., & Ablaku, B.E. (2011). Development and Nutritional Quality Evaluation of Kersting's Groundnut-Ogi for African Weaning Diet. *American Journal of Food Technology*, Vol. 6(12), pp. 1021-1033.

Australian Government National Health and Research Council. (2014). *The Nutrients Reviewed*. Retrieved on 10th June 2014 from http://www.nrv.gov.au/nutrients

Baskaran, A., Mahadevamma, N.G., Malleshi, S.G., Jayaprakashan, S.G., & Lokesh, B.R. (2001). Biological Evaluation for Protein Quality of Supplementary Foods Based on Popped Cereals and Legumes Suitable for Feeding Rural Mothers and Children in India. *Plant Foods for Human Nutrition*, Vol. 56, pp. 37-49.

Bender, D.A. (2005). *A Dictionary of Food and Nutrition*. New York, NY: Oxford University Press.

Bodwell, C.E., & Marable, N.L. (1981). Effectiveness of Methods for Evaluating the Nutritional Quality of Soy Bean Protein. *J. Am. Oil Chem. Soc.*, Vol. 3, pp. 475-483.

Boge, E.L., Boylston, T.D., & Wilson, L.A. (2009). Effect of Cultivar and Roasting Method on Composition of Roasted Soy Bean. *J. Sci. Food Agric.*, Vol. 89, pp. 829-826.

Boston University Research Compliance Committee. (2009). *Acclimation of Rodents*. Retrieved on 2nd Aug. 2013 from http://www.bu.edu/orccommittees/iacuc/policies-and-guidelines/acclimation-of-rodents/

Bukusuba, J., Isabiry, F., & Nampala, P. (2008). Enhancing Nutritional Density and Quality of Banana-Soy Based Complementary Diet through Substitution with Sesame. *African Journal of Food, Agriculture, Nutrition, and Development*, Vol. 8(1), pp. 104-117.

Burgess, A., & Glasauer, P. (2004). “Topic 7: Feeding Young Children Aged Over 6 Months.” In: Burgess, A., & Glasauer, P. (2004). *Family Nutrition Guide*. Rome: FAO of the United Nations

Chan, M. (2013). *The Global Nutrition Challenge: Getting a Healthy Start*. Retrieved on 5th July 2013 from http://WHO%20_%20The%20global%20nutrition%20challenge%20%20getting%20a%20healthy%20start.htm

Chen, K. (2012). Soy Foods and Soybean Products: From Traditional to Modern Applications. *Applied Biology & Biotechnology*, Vol. 96(1), pp. 9-22.

Collombet, R.N. (2013). *Investigating Soy Bean Market Situation in Western Kenya: Constraints and Opportunities for Small Holder Producers*. Minor Thesis in Plant Production Systems: PPS – 80424, Wageningen University.

Dewey, K.G. (2013). The Challenge of Meeting Nutrient Needs of Infants and Young Children during the Period of Complementary Feeding: An Evolutionary Perspective. *The Journal of Nutrition: Issues and Opinions*, Vol. 113, pp. 2050-2055.

Drake, M. A., Gerard, P. D., & Chen, X. Q. (2000). Effects of sweetener, sweetener concentration, and fruit flavor on sensory properties of soy fortified yoghurt. *IFT Annual Meeting Book of Abstracts*, p. 214, 86B-13.

Ekesa, B.N., Kimiywe, J., Davey, M.W., Dhuique-Mayer, C., Van Den Bergh, I., Karamura, D., & Blomme, G. (2012).Banana Plantain (*Musa spp*) Cultivar Preference, Local Processing Techniques, and Consumption Patterns in Eastern Democratic Republic of Congo. *International Journal of Agriculture Sciences*, Vol. 4(8), pp. 312-319.

FAO, IFAD, & WFP. (2013). *The State of Food Insecurity in the World 2013. The Multiple Dimensions of Food Security.* Rome, FAO.

FAO. (2012a). *Protein Digestibility and Absorption: Effects of Fibre and the Extent of Individual Variation*. Retrieved on 15th Aug. 2013 from http://www.fao.org/doCReP/MeetiNG/004/M2836e/M2836e00.HTM

FAO. (2012b). *Globally almost 870 Million Chronically Undernourished – New Hunger Report*. Retrieved on 16th June 2013 from http://FAO%202012%20-%C2%A0News%20Article%20%C2%A0Globally%20almost%20870%20million%20chronically%20undernourished%20-%20new%20hunger%20report.htm

FAO. (2011). *Dietary Protein Quality Evaluation in Human Nutrition*. FAO Food and Nutrition Paper 92: Report of an FAO Expert Consultation, Auckland, New Zealand.

FAO. (2004). *The Contribution of Nutrition to Achieving the Millennium Development Goals*. FAO's Nutrition and Consumer Protection Division, Geneva: Switzerland.

FAO/WHO. (2002). *Report of the Third Session of the Codex Ad Hoc Intergovernmental Task Force on Foods Derived from Biotechnology*. Yokohama, Japan, 4-8 March 2002.

FAO/WHO. (1998). *Carbohydrate in Human Nutrition*. Report of a Joint Expert FAO/WHO Consultation. FAO Food and Nutrition Paper 66. Food and Agriculture Organization, Rome.

FAO/WHO. (1991). *Protein Quality Evaluation*. FAO Food and Nutrition Paper 51, Bethseda, Md., USA.

Glover-Amengor, M., Quansah, J., & Peget, F.M. (2013). Performance and Acceptability of Legume-Fortified Yam Flours. *Food Science and Quality Management*, Vol. 17, pp. 14-20.

Hui, Y.H. (2006). *Handbook of Food Science, Technology, and Engineering* (Vol. 2). Boca Raon, FL: CRC Press.

ICRISAT. (2006). *Tropical Legume Farming in Kenya.* Bulletin of Tropical Legumes II Project, 2013.

Institute of Food Technologists. (1981). *Sensory Evaluation Guide for Testing Food on Beverage Products*. IFT, Food Technology, 1981.

Jacob, A. (2008). *First Foods: Expert Advice and Easy Recipes by Dieticians for Parents of 6-24 Months Olds*. New York, NY: Marshall Cavendish.

Jonas, C.N., Vanlauwe, B., Mahasi, J.M., Katungi, E., Akech, C., Mairura, F.S., Chianu, J., & Sanginga, N. (2008). *Soy Bean Situation and Outlook Analysis: The Case of Kenya.* Retrieved on 5th Sept. 2013 from http://www.icrisat.org/what-we-do/impi/projects/tl2-publications/regional-situation-outlook-reports/rso-sbean-kenya.pdf

Joseph, E., & Swanson, B.G. (1993). Growth and Nitrogen Retention of Rats Fed Bean (*Phaseolus vulgaris*) and Bean and Rice Diets. *Food Research International*, Vol. 26, pp. 261-269.

Kenya National Bureau of Statistics. (2009). *Kenya Demographic and Health Survey 2008-09*.

Kinyuru, J.N. *et al*. (2012). Identification of Traditional Foods with Public Health Potential for Complementary Feeding in Western Kenya. *Journal of Food Research*, Vol. 1(2), pp. 148-158.

Kramer, M.S. *et al*. (2002). Breastfeeding and Infant Growth: Biology or Bias? *Pediatrics*, Vol. 110(2), pp. 343-347.

Kure, O.A., & Wyasu, G. (2013).Influence of Natural Fermentation, Malt Addition, and Soya-Fortification on the Sensory and Physico-Chemical Characteristics of Ibyer-Sorghum Gruel. *Advances in Applied Science Research*, Vol. 4(1), pp. 345-349.

Lawless, H.T., & Heymann, H. (2010).*Sensory Evaluation of Food* (2nded.). New York, NY: Springer.

Lee, H.J. *et al*. (2011). Comparative Analyses of Total Phenols, Flavanoids, Saponins and Antioxidant Activity in Yellow Soy Beans and Mung Beans. *International Journal of Food Science and Technology*, Vol. 46, pp. 2513-2519.

Mahasi, J.M. et al. (2012). *Increasing Productivity of Soy Bean in Western Kenya through Evaluation and Farmer Participatory Variety Selection*. KARI, Njoro: CIAT-Nairobi TSBF.

Mariam, S. (2005). Nutritive Value of Three Potential Complementary Foods Based on Cereals and Legumes. *African Journal of Food, Agriculture, Nutrition, and Development*, Vol. 5(2), pp. 2-15.

Mosha, T.C.E., & Vicent, M.M. (2005). Nutritional Quality, Storage Stability and Acceptability of Home-Processed Ready-To-Eat Composite Foods for Rehabilitating Undernourished Pre-School Children in Low Income Countries. *Journal of Food Processing and Preservation*, Vol. 29, pp. 331-356.

Mosha, T.C.E., & Bennink, M.R. (2004).Protein Quality of Drum-Processed Cereal-Bean-Sardine Composite Supplementary Foods for Preschool-Age Children. *Journal of the Science of Food and Agriculture*, Vol. 84, pp. 1111-1118.

Mosha, T.C.E. & Vicent, M.M. (2004).Nutritional Value and Acceptability of Homemade Maize/Sorghum-based Weaning Mixtures Supplemented with Rojo-Bean Flour, Ground sardines and peanut paste. *International Journal of Food Sciences and Nutrition*, Vol. 55(4), pp. 301 – 315.

Nassar N.M.A. & Sousa, M.V. (2007).Amino Acid Profile in Cassava and Its Interspecific Hybrid. *Genetic and Molecular Research*, Vol. 6(2), pp. 292-297.

National Research Council Manual. (2011). *Guide for the Care and Use of Laboratory Animals* (8thed.). Washington, D.C: The National Academies Press.

Nicklaus, S. (2011). Children’s Acceptance of New Foods at Weaning. Role of Practices of Weaning and Food Sensory Properties. *Appetite*, Vol. 57(3), pp. 812-815.

Nyaga, D.R. (2012). *Breast-feeding and Weaning Practices among Rural and Urban Mothers of Embu District, Kenya*. Retrieved on 27th April 2013 from http://ir-library.ku.ac.ke/ir/handle/123456789/2286?show=full

Nungo, R.A., Okoth, M.W., & Mbugua, S.K. (2012). Nutrition Status of Children Under Five Years in Cassava Consuming Communities in Nambale, Busia of Western Kenya. *FNS*, Vol. 3(6), pp. 796-801.

Odenigbo, M.A., Asumugha, V.U., Ubbor, S., Nwauzor, C., Otuonye, A.C., Offia-Olua, B.I, Princewill-Ogbonna, I.L. et al. (2013). Proximate Composition and Consumption Pattern of Plantain and Cooking Banana. *British Journal of Applied Science & Technology*, Vol. 3(4), pp. 1035-1043.

Ogunleye, R.F., & Omotoso, O.T. (2005). Edible Orthopteran and Lepidopteran as Protein Substitutes in the Feeding of Experimental Albino Rats. *African Journal of Zoology & Environmental Biology*, Vol. 7, pp. 48-51.

Okalebo, J.R., Gathua, K.W., & Woomer, P.L. (2002).*Soil and Plant Analysis: A Working Manual* (2nded.). Nairobi: TSBF-CIAT and SACRED Africa, Kenya.

Olatidoye, O.P. & Sobowale, S.S. (2011). Effect of Full-Fat Soy-Bean Flour on the Nutritional, Physiochemical Properties and Acceptability of Cassava Flour. *Electronic Journal of Environmental, Agricultural and Food Chemistry*, Vol. 10(3), pp. 1994-1999.

Onofiok, N.O. & Nnanyelugo, D.O. (2012). *Weaning Foods in West Africa: Nutritional Problems and Possible Solutions*. Retrieved on 3rd July 2013 from http://Weaning%20foods%20in%20West%20Africa%20%20Nutritional%20problems%20and%20possible%20solutions.html

Peryam, D.R., & Pilgrim, F. (1957). Hedonic Scale Method of Measuring Food Preference. *Food Technology*, Vol. 11, pp. 9-14.

Rai, M., Rai, A., & Pandey, S. (2007). Study of Weaning Practices of Infants in Selected Rural and Urban Communities of Azamgarh District. *Indian Journal of Prevalent Social Medicine,* Vol. 38(4), pp. 123-143.

Riaz, M.N. (2006). *Soybeans Processing into Ingredients*. Retrieved on 25th July 2013 from http://www.wishh.org/workshops/intl/southafrica/sept06/riaz1-sept06.pdf

Rutherford, S.M., & Maughan, P.J. (2007). Development of a Novel Bio-Assay for Determining the Lysine Content for Foods and Feed Stuff. *Nutr. Res. Rev*., Vol. 20, pp. 3-16.

Sarwar, G., Peace, R.W., Botting, H.G., & Brule, D. (1989).Digestibility of protein and amino acids in selected foods as determined by a rat balance method. *Plant Food Human Nutrition*, Vol. 39, pp. 23–32

Serrem, C.A., de Kock, H.L., Oelofse, A., & Taylor, J.N.R. (2011).Rat Bioassay of the Protein Nutritional Quality of Soy Fortified Sorghum Biscuits for Supplementary Feeding of School-age Children. *Department of Food Science, University of Pretoria*, SA. Pp. 1-26.

Shidfar, F. *et al*. (2009).Effects of Soy Bean on Serum Paraoxonase 1 Activity and Lipoproteins in Hyperlipidemic Postmenopausal Women. *International Journal of Food Science and Nutrition*, Vol. 60(3), pp. 195-205.

Stabursvik, A., & Heide, M. (1974).Protein Content and Amino Acid Spectrum of Finger Millet [*Eleusinecoracana*) (L.) Gaerttn.] as Influenced by Nitrogen and Sulphur Fertilizers. *Plant and Soil*, Vol. 41(3), pp. 549-571.

UNICEF, WHO, and WB. (2012). *Levels and Trends in Child Malnutrition*. UNICEF, New York; WHO, Geneva; The World Bank, Washington, DC; 2012.

UNICEF. (2013). *Improving Child Nutrition: The Achievable Imperative for Global Progress.* New York, NY: UNICEF 2013.

UNICEF. (2012). *Child Malnutrition*. New York, NY: 2012.

UNICEF. (2006). *Nutrition and the MDGs.* Progress for Children: A Report Card on Nutrition, No. 4, May 2006. Retrieved on 23rd Dec. 2013 from http://www.unicef.org/progressforchildren/2006n4/index_nutritionandmdgs.html

UNDP. (2012). *Africa Human Development Report 2012*. Retrieved on 30th April 2013 from http://www.afhdr.org/the-report/

USAID-IYCN. (2010). Engaging Men to Increase Support for Optimal Infant Feeding in Western Kenya. *USAID APHIA II Western 5th Breastfeeding and Feminism Symposium,* August 2010.

USDA. (2013). *National Nutrient Database for Standard Reference Release 26*.The National Agricultural Library, 2013.

US Department of Agriculture. (2012). *Oilseeds: World Markets and Trade*. Retrieved on 19th Dec. 2012 from *"Growing Crush Limits India's Soy Oil Imports"*

USDA. (2010). *USDA Food and Nutrient Database for Dietary Studies, 4.1*.Bestville, MD: USDA, Agricultural Research Service, Food Surveys Research Group.

Vaclavik, V., & Christian, E.W. (2013). *Essentials of Food Science*. New York, NY: Springer Science & Business Media.

Van der Merwe, J,M, Kluyts, M., Bowley, N., & Marais, D. (2007). Optimizing the Introduction of Complementary Foods in the Infant's Diet: A Unique Challenge in Developing Countries. *Maternal and Child Nutrition*, Vol. 3(4), pp. 259-270.

Vasconcelos, I. M., Maia, A. A. B., Siebra, E. A., Oliveira, J. T. A., Carvalho. A. F. F. U., Melo, V. M. M., Carlini, C. R., and Castelar, L. I. (2001).Nutritional study of two Brazilian soybean (*Glycine max*) cultivars differing in contents of anti-nutritional and toxic proteins. *Journal of Nutritional Biochemistry,* Vol. 12, pp. 55-62.

Warren Photographic.(2014). *Albino Rat Tripoding*. Retrieved on 31st July 2014 from http://www.warrenphotographic.co.uk/10510-albino-rat-tripoding

WHO. (2013). *Infant and Young Child Feeding: Key Facts*. Retrieved on 2nd Jan 2014 from http://www.who.int/mediacentre/factsheets/fs342/en/index.html

WHO/FAO/UNU. (2007). *Protein and Amino Acid Requirements in Human Nutrition.* WHO Technical Report Series 935. Geneva; Switzerland.

WHO. (2003). *Global Strategy for Infant and Young Child Feeding*. Geneva: Switzerland.

Witteman, C.L.M. *et al*. (2012). Clinical Intuition in Mental Health Care: A Discussion and Focus Groups. *Counseling Psychology Quarterly*, Vol. 25(1), pp. 19-29.

Wu, W., Williams, P.W., Kunkel, M.E., Acton, J.C., Huang, Y., Wardlaw, F.B., & Grimes, L.W. (1995). True Protein Digestibility and Digestibility-Corrected Amino Acid Score of Red Kidney Beans (*Phaseolus vulgaris L*.).*J. Agric. Food Chem*., Vol. 43, pp. 1295-1298.

Young, V.R., & Pellet, L.P. (1994). Plant Protein in Relation to Human Protein and Amino Acid Nutrition. *American Journal of Clinical Nutrition*, Vol. 59, pp. 1203S – 1212S.

APPENDICES

Appendix 1: Consent Form

I am Elijah Kamau, a post-graduate student at the University of Eldoret pursuing a Masters degree in Community Nutrition. I am currently undertaking a research project entitled “Nutrient Composition, Efficacy, and Consumer Acceptability of soy fortified complementary foods from Western Kenya.” With reference to this, I am conducting a consumer evaluation for soy fortified porridges made of pearl millet, finger millet, cassava, bananas, sorghum, and maize. My target population is parents with children aged two years and below.

Carefully read this and sign at the bottom if you agree to participate in the study:

I am well informed of the nature of this study and I understand that participation is on the basis of informed consent. I further agree that I meet the inclusion criterion and I am not allergic to soy or any of the flours used in preparing the samples for this study.

Name: …………………………

Sign …………………………..

Date: …………………………

Appendix 2: Consumer Evaluation Score Card

Welcome to this porridge testing session

Age: Gender: SET NUMBER:

You are presented with six (6) samples of porridge. Please taste the samples in the order provided from left to right. Take a sip of water before you start tasting and in between tasting different samples. Indicate your liking or dislike by placing a check (X) at the appropriate point on the scale.

Sample Code												
	Color	**Smell**	**Taste**	**Texture**	**Color**	**Smell**	**Taste**	**Texture**	**Color**	**Smell**	**Taste**	**Texture**
Like extremely												
Like very much												
Like moderately												
Like slightly												
Neither like nor dislike												
Dislike slightly												
dislike moderately												
dislike very much												
dislike very much												
Dislike extremely												

Sample Code												
	Color	**Smell**	**Taste**	**Texture**	**Color**	**Smell**	**Taste**	**Texture**	**Color**	**Smell**	**Taste**	**Texture**
Like extremely												
Like very much												
Like moderately												
Like slightly												
Neither like nor dislike												
Dislike slightly												
dislike moderately												
dislike very much												
dislike very much												
Dislike extremely												