NUTRITIONAL AND SENSORY QUALITY OF EXTRUDED PEANUTS-SOYBEANS-CASSAVA COMPOSITE FLAKES FOR REHABILITATING ACUTELY MALNOURISHED CHILDREN

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A DISSERTATION SUBMITTED IN PARTIAL FULFILEMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN HUMAN NUTRITION OF SOKOINE UNIVERSITY OF AGRICULTURE. MOROGORO, TANZANIA.

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ABSTRACT

This study was conducted to evaluate the nutritional and sensory quality of extruded peanuts-soybean-cassava composite flakes for rehabilitating acutely malnourished children. The product was formulated from peanuts, soybeans and cassava flour to achieve the desired levels of protein and energy as recommended by FAO/WHO/UNU. The peanuts-soybeans-cassava mixture was extruded to flakes which were then analyzed for nutritional and sensory qualities. Results showed that, extruded peanut-soybeans-cassava composite flakes had good quality due to their ability to support growth in rats with good PER value of 2.32 and true protein digestibility of 93.99%. The nutrient composition of peanuts-soybeans-cassava flakes per 100 g was as follows: protein content-(14.28 g), carbohydrate-(25.45 g), crude fat content-(32.27 g), ash-(5.16 g), and crude fibre content-(22.89 g). Mineral composition of peanuts-soybeans-cassava flakes per 100 g was as follows: phosphorous-(427.8 mg), selenium-(8.24 mg), lead-(1.02 mg), copper-(1.74 mg), iron-(30 mg), zinc-(12.14 mg), calcium-(713.42 mg), magnesium-(367.3 mg), potassium-(703.95 mg) and sodium-(118.6 mg). Extruded ready-to-eat peanuts-soybeans-cassava composite flakes had good sensory quality and were highly acceptable. It was concluded based on the results that, peanuts-soybeans-cassava composite flakes can be used as a therapeutic food for rehabilitating under-nourished children much the same as the plumpy nut. It is therefore recommended that, the product needs more research on shelf life and evaluation of anti-nutritional factors and microbial quality before it can be routinely used to rehabilitate undernourished children.

DECLARATION

I, DOMINA LEONCE SWAI, declare to the Senate of Sokoine University of Agriculture, that this dissertation is my own original work done within the period of registration and that it has neither been submitted nor being concurrently submitted in any other institution for a degree award.

DOMINA LEONCE SWAI Date

(MSc. Human Nutrition Candidate)

The above declaration is confirmed:

Prof. MOSHA, T. C. E. Date

(Supervisor)

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This work is dedicated to my beloved Grandmother Mrs. Sharipha Murugale and my parents Mr. Leonce Swai and Batuli Isaack Kimaro who laid down the foundation of my education and shaped me to what I am today.

I also dedicate this work to all children who are acutely undernourished and who will find this food (Peanut-soybeans-cassava composite flakes) a source of relief to ameliorate their condition.

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LIST OF ABBREVIATIONS AND SYMBOLS

%	Percentage
<	Less than
>	Greater than
µg	microgram
AOAC	Association of Official Analytical Chemists
APD	Apparent Protein Digestibility
Ca	Calcium
CAC	Codex Alimentarius Commission
Cu	Cupper
DM	Dry matter
FAO	Food and Agriculture Organization of the United Nations
Fe	Iron
g	gram
GLM	General linear model
HTST	High Temperature Short Time
IFRC	International Federation of Red Cross
IMAM	Integrated Management of Acute Malnutrition
K	Potassium
kcal	Kilo calories
kg	Kilogram
kJ	kilojoules
MAM	Moderately Acute Malnutrition
MDGs	Millennium Development goals

Mg	Magnesium
mg	Milligram
MHSW	Ministry of Health and Social Welfare
Na	Sodium
nm	Nanometer
NURU	Nutrition Rehabilitating Unit
P	Phosphorous
Pb	Lead
PDCAA	Protein digestibility corrected amino acids
PER	Protein Efficiency Ratio
PN	Plumpy nuts®
PSC	Peanuts-soybeans-cassava
RCS	Red Crescent Societies
RNI	Recommended nutrient intake
RUTF	Ready to Use Therapeutic Food
SAM	Server Acute Malnutrition
SAS	Statistical Analytical System
SD	Standard Deviation
Se	Selenium
SUA	Sokoine University of Agriculture
TFNC	Tanzania Food and Nutrition Centre
TPD	True Protein Digestibility
UNHCR	United Nations High Commissioner for Reugees
UNICEF	United Nations Children Fund

UNU	United Nations University
WFP	World Food Programme
WHO	World Health Organization
Zn	Zinc

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Information

Malnutrition is one of the challenges facing Tanzania as it contributes to under-five mortality. In the past decade, over 600 000 children under the age of five years died as a result of inadequate nutrition (UNICEF, 2009). There are two forms of malnutrition namely; - under- and over nutrition. Over nutrition is a condition where the body gets too much energy, especially fats and sugars while under-nutrition is a condition in which the body does not get enough of the right kind of food to meet its energy, macronutrients (proteins, carbohydrates and fats) and micronutrient (vitamins and minerals) needs. Children can still be undernourished even if they have enough food to meet their energy requirements, especially if that food lacks essential micronutrients (Pridmore *et al*., 2009).

Under-nutrition greatly impedes countries' socio-economic development and potential to reduce poverty. It is a major constraint to attain many of the Millennium Development Goals (MDGs) – particularly MDG 1 (eradicate extreme poverty and hunger), MDG 4 (reduce child mortality) and MDG 5 (improve maternal health) (UNICEF, 2009).

In additional, under-nutrition results in increased infections such as lower respiratory tract infections, malaria and measles, and contributes to higher mortality rate associated with infectious diseases among children below the age of five years

(WHO, 2005). Chronic under-nutrition in early childhood results in diminished cognitive and physical development putting those children who do survive at a disadvantage for the rest of their lives (WHO, 2005).

In Tanzania, the trend of under-nutrition remained relatively constant from 1992 to 1999, however, prevalence of stunting, underweight and wasting decreased from 44, 29 and 5% in 1999 to 38, 22 and 3%, respectively, in 2005. Remarkable change was reported in 2010 whereby, stunting, under-weight and wasting increased to 42, 16, and 5%, respectively. This suggested that, no enough efforts were made to address the problem of under nutrition in Tanzania (NBS (Tanzania)/ICF and Macro, 2011).Severe Acute Malnutrition (SAM) among children under the age of 5 years is common in Tanzania and most affected regions are Arusha, Zanzibar, Dar es Salaam, Kilimanjaro, Mwanza, Mara, Morogoro, Tanga and Singida (NBS (Tanzania)/ICF and Macro, 2011).

The strategies to eliminate malnutrition in Tanzania started in the late 1960s in which NURUs (Nutrition Rehabilitation Units) were established in major hospitals. NURUs aimed at managing children with severe under-nutrition through proper child feeding and appropriate nutrition education to the mothers. However, treatment of severely malnourished children in nutrition rehabilitation centers did not prevent recurrence of malnutrition nor its appearance in siblings. As an alternative, community–based nutrition rehabilitation approach was established in 1975 where treatment was carried out in the communities. Emphasis was placed on having parents and community members participate in the management of the under-nutrition (TFNC, 2006).

Tanzania adopted integrated management of acute malnutrition (IMAM) with the aim of reducing deaths from severe acute malnutrition by active-case finding and early intervention before the child's condition deteriorates. Children were thus screened and identified within the community. Severely malnourished children with complications were managed as inpatient with provision of F-75 therapeutic milk formula and ReSoMo (rehydration solution) used for treating dehydration at initial phase of rehabilitation. Upon improvement, children were given F-100 milk formula or ready-to-use therapeutic food such as corn-soy-meal or Plumpy Nut® (TFNC, 2006).

Most children who recovered from SAM, relapsed into the same problem as they return to family meals which caused them the problems. According to IMAM model, children discharged from the wards should be moved to outpatient departments where they should receive nutrition counseling and dietary supplementation with ready-to-use therapeutic food (Plumpy nut). Plumpy nut is a peanut-based paste composed of sugar, vegetable fat, and skimmed milk powder and enriched with vitamins and minerals. As a ready-to-use food, it can be consumed directly from the sachet. Plumpy nut is imported from France but currently it is produced by Power Foods Company in Dar es Salaam. Plumpy nut is distributed as a prescription supplement through the Medical Store Department. It is therefore not possible to access plumpy nut from outside the medical line (Medical Store Department). The children with SAM who are discharged from hospitals can no longer access Plumpy nut as they return to their homes. There is therefore the need to develop a nutrient rich composite product that would bridge the gap of nutritional requirements for

SAM children who are discharged from health facilities (Nutriset, 2008). Therefore, locally available foods such as peanuts, soybean and cassava which are good sources of nutrients and energy can be used to formulate ready to use therapeutic foods that would be readily available outside the medical line and can be used as a plumpy nut substitute to save the same purpose of rehabilitating under-nourished children after they have been discharged from rehabilitation centers.

1.2 Problem Statement and Justification

Acute malnutrition remains a persistent problem for young children in sub-Saharan Africa. A high percentage of under-five children fail to reach the normal height for their age due to persistence under-nutrition. Moreover, the number of undernourished children in sub-Saharan Africa continues to increase and the region has shown little improvement over the past decades (Picot *et al.,* 2012). In Tanzania, prevalence of under-nutrition among under five children is very high, with 42% of children classified as stunted, 5% wasted and 16% as underweight (NBS (Tanzania)/ICF and Macro, 2011).

Severe malnutrition with complications requires inpatient management. The management comprises of short stabilization phase to treat life-threatening conditions whereby the children are given F75 milk formula for promoting recovery of normal metabolic functions and electrolyte balance. When these children start recovering and have good appetite, they are shifted to transition phase where they receive F100 milk formula or RUTF usually Plumpy Nut® or corn-soy meal. In phase two, children are also given F-100 or Plumpy Nuts®, the food recommended by WHO for phase two management of SAM (Ashworth, 2001; WHO, 2010). Those formulas are designed for patients to rapidly gain weight (more than 8 g/ kg/day). In the rehabilitation phase, if children receive appropriate dietary treatment, rapid weight gains (i.e. catch-up growth) can be achieved, enabling severely wasted children to ‘recover’ in about 4-6 weeks. Children are considered to have recovered when they attain +1SD of their weight for height (Chevalier *et al.*, 1998).

Many hospitals discharge children before they attain +1SD weight-for-height. Early child discharge in rehabilitation centers is associated with many dangers such as relapsing into under-nutrition due to their home diet which is poor and inadequate to support catch up growth, and their poor immunity which is still impaired and thus are prone to repeated infections that lead to increased risk of death (Chevalier *et al*., 1998). According to Ashworth (2001), Kenyan and Tanzanian children who were discharged after having been treated in hospital died while others remained malnourished and had to be readmitted into the health centers. The reasons for remaining malnourished were the poor home-based management they were given especially lack of nutritious foods and poor health services (Ferguson *et al*., 2008).

Availability of ready to use therapeutic foods (RUTF) is important in strengthening home-based management of severely malnourished children. Ready-to-use therapeutic food is an energy-dense food enriched with minerals and vitamins, with a nutrient profile similar to plumpy nut but greater energy and nutrient density than F100. This diet is suitable for the recovery phase of the treatment of severe acute under-nutrition (Briend, 2001). Ready-to use therapeutic foods especially plumpy-nut have greatly eased the difficulties associated with providing suitable high-energy, nutrient-dense foods that are safe for use in outpatient programs. However, availability of Plumpy Nut® is limited to inpatients. Once they are discharged from health centers they no longer get access to the supplement. There is therefore a critical lack of an affordable nutritious product (RUTF) in the market that can easily be used to provide the needed nutrients for children who have been discharged from health centers. There is thus a need to develop a nutrient dense, high calorie product (RUTF) which can fill the nutritional gap for children who have just been discharged from health facilities. The food was formulated from peanut, soybean and cassava and extruded into flakes and fortified. This would provide a well-balanced nutritious supplement for children who have just been discharged from health centers and would be used in place of plumpy nut. The product can also serve as an effective supplement for rehabilitating under-nourished children in rural communities in Tanzania.

1.3 Objectives of the Study

1.3.1 General objectives

The general objective of the study was to develop high calories/nutrient dense extruded peanut-soybean-cassava composite flakes for rehabilitating undernourished children.

1.3.2 Specific objectives

The specific objectives of the study were:-

(i) To formulate a peanut-soybean-cassava composite product

(ii) To evaluate the nutritional quality of the peanut-soybean-cassava composite product using rat model

(iii) To determine the chemical composition of the peanut-soybean-cassava composite flakes.

(iv) To determine sensory quality and acceptability of the peanut-soybean-cassava.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Under Nutrition

Under-nutrition exists when inadequate food intake and repeated infections lead to one or more of the following conditions: low height for the age (stunting), low weight for the height (wasting) and/or low weight for the age (underweight). Another form of under-nutrition consists of deficiencies of essential micronutrients which are vitamins and minerals, especially iron, iodine, zinc and vitamin A. Micronutrient deficiencies are also referred to as ‘hidden hunger’ because they are often present without showing any clinical signs, and may remain undetected until they become very severe and life-threatening (IFRC and RCS, 2011). Under-nutrition is a cause of more than one–third of children deaths in Tanzania (Aston and Jones, 2012).

2.2 Prevalence of Micronutrients Deficiency

Micronutrient deficiencies are highly prevalent in low-income countries, and the most probable causes are low content in the diet and poor bioavailability. It is estimated that, 33% (190 million) of preschool age children do not have enough vitamin A in their daily diet. Higher levels of vitamin A deficiency are found in Africa and some part of Asia, where more than 40% of preschool age children are estimated to be vitamin A deficiency. Further, about 25% of the world population, most of them being children have iron deficiency (UNICEF, 2009). In Tanzania, 35% of children are iron deficiency while 59% have anemia. Overall, prevalence of iron deficiency anemia among children is 24%, while the rate of iron deficiency without anemia is 11%. Likewise, vitamin A deficiency, which is the most common cause of blindness in low- and middle-income countries, affects about 33% of children aged 6 – 59 month (NBS (Tanzania)/ICF and Macro, 2011). Zinc deficiency is common among children in developing countries including Tanzania, due to intake of foods low in zinc. Foods from animal sources are good source of zinc. There is also limited zinc bioavailability from plant based diets (Shrivastava *et al*., 2001).

2.3 Causes of Under-nutrition

Under-nutrition is regarded as one of the public health problems in developing countries as a result of poor feeding practices which are associated with poverty. According to the global conceptual framework (Appendix 1), under-nutrition results directly from inadequate dietary intake and infectious diseases which are immediate causes. It is also due to underline causes which include household food insecurity, inadequate maternal and child care, poor access to health services, and unhealthy environment (MHSW, 2011). Poverty is also a root couse of under-nutrition. According to NBS (Tanzania)/ICF and Macro (2011) 44% of Tanzania household is food insecure because they lack the resource to purchase sufficient food for the household members.

In Tanzania, it is estimated that 49% of infant are breast fed within one hour of birth and only 50% of the infant aged less than 6 months are exclusively (NBS (Tanzania)/ICF and Macro, 2011). Poor feeding, poor nutrition quality of complementary food and poor timing of feeding enhance the problem of under-nutrition. It is estimated that, 93% of infants aged 6-9 months are receiving complementary foods, however, the frequency and quality of these foods is often inadequate (MHSW, 2011). Under-nutrition can also be contributed by poor resource allocation. According to the Ministry of Health and Social Welfare (2011), poor economic structure of the government contributes to poor resource allocation. As a result, there is little concern to important aspect such as health and sanitation. MHSW report (2011) shows that, many households in Tanzania live in unhealthy conditions and only about 54% have access to clean and safe water while less than 10% of households have access to ventilated improved pit latrine or flush toilets.

2.4 Complementary Feeding

Complementary feeding is defined as the process starting when breast milk alone is no longer sufficient to meet the nutritional requirements of an infant, and the child start receiving nutrients from other foods to complement the nutrients from the mother’s milk. Complementary foods need to be rich in calories and nutrients and must be highly digestible and bioavailable. It is usually introduced to the infant after six months (Dewey, 2001). After the period of exclusive breastfeeding (six months), children have a high demand for nutrients and these nutrients must be supplied from the complementary foods. Unfortunately, most of the complimentary foods given to the children are low in calories, macro- and micro-nutrients and thus cannot support optimal growth of most children. Traditional supplementary foods in Tanzania are based on starchy staples, usually cereals such as maize, rice, sorghum and finger millet and non-cereals such as cassava, sweet potatoes, yams, bananas and plantains (Mosha *et al*., 2000). Such foods are usually low in high quality protein and micronutrients (Kikafunda *et al*., 2006). Over dependence on such poor protein sources is the main cause for the widespread protein-energy under-nutrition in many areas. Major food-related causes of malnutrition include inadequate feeding, foods with low energy and nutrient density, low bioavailability of nutrients, poor access to food, use of poor processing methods and microbial contamination (Ijarotimi and Ashipa, 2005).

Growth of children starts to falter during supplementation and/or thereafter. Under-nutrition and micronutrients deficiencies become a serious problem during this period, as most supplementary foods given to infants do not supply adequate amount of nutrients needed to support optimal growth. This period is also accompanied by high incidences of childhood diseases because of increased infections such as diarrhea that adversely affect growth and nutritional status of a child (Gibson and Furguson, 1998). Sub optimum complementary feeding is clearly a determinant of stunting due to the fact that the complimentary foods are often low in calories and micro-nutrients insufficient to support optimal growth.

2.5 Acute Malnutrition

Acute malnutrition is also known as wasting and is characterized by rapid deterioration in nutritional status over a short period of time. Acute malnutrition exists at different levels; moderate acute malnutrition (MAM) and severe acute malnutrition (SAM). Acute malnutrition arises as a consequence of sudden period of food shortage and is associated with loss of body fat and wasting of skeletal muscle (Picot *et al.,* 2012). In developing countries, some 19 million children under five years of age are severely wasted. In 2004, approximately 310 000 deaths among these children in Africa, Asia and Latin America were attributed to severe wasting. Forms of SAM include kwashiorkor, marasmus and marasmic kwashiorkor (Picot *et al.*, 2012).

The risk of mortality in acute malnutrition is directly related to severity: moderate wasting is associated with a mortality rate of 30–148 per 1000 children per year while severe wasting is associated with a mortality rate of 73–187 per 1000 children per year. This equates to over 1·5 million child deaths associated with severe wasting and 3·5 million with moderate wasting every year (Collins *et al.*, 2006). According to NBS (Tanzania)/ICF and Macro, 2011), 5% of under five children are wasted (low weight for height) which reflects acute under nutrition.

2.6 Management of Acute Malnutrition

Acute malnutrition carries a high risk of death and requires therapeutic treatment for recovery. Management of acute malnutrition combines outpatient treatment of cases of SAM with no medical complications, including the absence of severe oedema and serious infection, with inpatient treatment to stabilize those cases that present with complications (Puett *et al*., 2012).

Since acute malnutrition is a major risk factor for child mortality, proper treatment of moderate acute malnutrition is required to reduce or prevent the progression toward severe acute malnutrition. In this context, moderately malnourished children have different requirements than health children with good nutritional status. In additional to that moderate acute malnourished children have increased nutritional needs to meet for the needs of the catch up growth in weight and height. Also, they have increased needs to fight off infections and diseases (Karakochuk, 2010). Recommended Nutrient Intakes (RNI) for moderate acute malnutrition has been devised and is available for the management of severe acute malnutrition and moderately acute malnutrition cases. Table 1 summarizes the recommended nutrient intake for moderate acute malnourished children according to Golden (2009).

Table 1: Recommended nutrient intake (unit/1000kcal) proposed for moderately acute malnutrition (MAM)

		RNIs for normal children		F 100 and RUTF	RNIs for MAM	
Nutrients	Gravimetric	FAO	Others	SAM	Food	Supp
Protein						
protein	g	22.3	-	28.4	24	26
Nitrogen	g	3.6	-	4.6	3.9	4.2
Minerals						
Sodium	mg		978	434	550	550
Potassium	mg		1099	2400	1400	1600
Magnesium	mg	79	112	175	200	300
phosphorous	mg	450	634	762	600	900
Sulphur	mg	0	0	0	0	200
Zinc	mg	12.5	16.5	22.3	13	20
Calcium	mg	595	820	1009	600	840
Copper	µg		892	2749	680	890
Iron	mg	17.8	17.8	24d	9	18
Iodine	µg	201	201	190	200	200
Selenium	µg	17.8	29.7	55	30	55
Manganese	mg		1.2	0.69	1.2	1.2
Chromium	µg		10.8	0	0	11
Molybdenum	µg		16.6	0	0	16
Water soluble vitamin						
Thiamine (B1)	µg	523	523	700	600	1000
Riboflavin (B2)	µg	595	595	2000	800	1800
Pyrodoxine (B6)	µg	595	732	700	800	1800
Cobalamine (B12)	ng	966	966	1000	1000	2600
Folate	µg	167	167	350	220	350
Niacine	mg	6.4	8.4	10	8.5	18
Ascobate	mg	45	74	100	75	100
Pantothenic acid	mg	2.7	2.7	3	2.7	3
Biotin	µg	9.7	9.7	24	10	13
Fat soluble vitamin						
Retinal (Vitamin A)	µg	595	743	1500	960	1900
Cholecaciferol (vitamin D)	µg	7.4	10.9	30	7.4	11
Tochopherol (Vitamin E)	mg	8.9	8.9	22	11.5	22
Phytomenadione (vitamin K)	µg	16.1	16.1	40	20	40
Essential fatty acids						
N-6 fatty acid	g			5	5	5
N-3 fatty acid	g			0.85	0.85	0.85
Others						
Choline	mg		223		223	223
Histidine	mg		430		430	430
Isoleucine	mg		575		575	575
Leucine	mg		1245		1245	1245
Lysine	mg		1190		1190	1190
Methionine + cystine	mg		575		575	575
Phenylalanine + tyrosine	mg		1125		1125	1125
Threonine	mg		655		655	655
Tryptophan	mg		175		175	175
Valine	mg		776		776	776

Source; Golden (2009)

2.7 Nutrition Rehabilitation

The role of rehabilitating severely undernourished children is to correct children's weight deficits and to teach mothers on child feeding and health care. According to Ashworth *et al.* (2003), acute malnourished children with complications should be managed in hospital until the weight for length improves to above 90%. The treatment will involve those aspects which prevent hypoglycemia, hypothermia, dehydration, infection and those correcting electrolyte imbalance and micronutrient deficiencies. Also, treatment should improve feeding, achieve catch-up growth, and provide sensory stimulation and emotional support as well as ensuring follow-up after recovery (Ashworth *et al.*, 2003).

Severely malnourished children in the rehabilitation centers are given ReSoMol and F-75 (75 kcal/100 ml) at the initial phase of treatment followed by F-100 (100 kcal/100 ml) during the rehabilitation phase (Ashworth *et al.*, 2003). After improvement children are given Plumpy Nut® developed by Nutriset. According to Ashworth (2001), children attending well-operated NRCs have shown a good catch up growth of more than 70-80%, although the actual rates of recovery were slow, primarily due to low energy intakes. In a clinical trial involving severely malnourished children in Senegal, energy intakes (808 kJ/kg/day vs 573 kJ/kg/day), rates of weight gain (15·6 g/kg/day vs 10·1 g/kg/day), and time to recovery were significantly greater in those receiving ready-to-use therapeutic food than in those receiving F100 (Diop *et al.*, 2003).

2.8 Ready to Use Therapeutic Food

Ready-to-use therapeutic foods (RUTF) are foods with high energy and nutrient density necessary to support rapid catch-up growth. It is used particularly in the treatment of children over six months of age with severe acute malnutrition but without medical complications. Majority of RUTFs are lipid-based products based on a paste of peanuts, sugar, milk powder and micronutrient mix, with low risk of contamination and a long shelf-life. Example; Plumpy nut that is produced and distributed by the French company-Nutriset and a type of biscuit called BP-100 are compressed into a bar. Ready to use food are both used for treating inpatient and outpatient malnourished children (UNHCR, 2011; Nutriset, 2008).

Plumpy nut is a ready to eat therapeutic food composed of a peanut-based paste, with sugar, vegetable fat and skimmed milk powder and fortified with vitamins and minerals. It is available in 92 g sachets which provide 500 kcal, and it can be used for up to 24 months after the date of manufacture without refrigeration. As a ready-to-use food, plumpy nut requires no preparation, no dilution in water prior to use, no cooking, and it can be consumed direct from the sachet (Nutriset, 2008). Nutrition composition of the plumpy nut is presented in Table 2.

Table 2: Nutritional composition of Plumpy nut®

Nutrients	Unity	Per 92g	Per 100g
Energy	kcal	500	543.47
Protein	g	12.5	13.5
Lipids	g	32.86	35.7
Calcium	mg	276.0	300
Phosphorus	mg	276.0	300
Potassium	mg	1022.0	1110.86
Magnesium	mg	84.6	91.95
Zinc	mg	12.9	14
Copper	mg	1.6	1.74
Iron	mg	10.6	11.5
Iodine	µg	92	100
Selenium	µg	27.6	30
Sodium	mg	<267	<290

Source: Nutriset (2008)

Ready to eat therapeutic food especially Plumpy nuts® is easily used at home by the mothers and care givers. The food can be stored at home with little risk of microbial contamination. Since Plumpy nut® is based in milk and large number of malnourished people live in developing countries where milk and other animal-derived products are expensive, there is a need for a therapeutic food that does not include milk and dairy products.

2.9 Cassava and its Nutritional Values

Cassava (*Manihote esculenta*), also called manioc, tapioca or yucca is one of the most important food crops in humid tropic, being particularly suited to conditions of low nutrients availability and able to survive drought. The plant grows to height of 1 to 3 m and several roots may be found on each plant (Tnukan, 2004). Cassava roots have optimum harvest age beyond which a loss in yield occurs. During that time, the roots become woody hence flavor is reduced. During storage, there is a danger that roots may be infested by pathogens. Cassava roots are usually peeled and soaked in water for fermentation which enables softening of the roots and easy leaching of cyanogens prior to processing. After peeling, the roots are reduced in size by chipping or grating, and where machines are not available these processes are done manually. Cassava is an energy-dense food and therefore ranked high for its calorific value of 145.93 kcal per 100 g fresh weight than other root crops such as sweet potatoes 110.05 kcal per 100 g. The root is a physiological energy reserve with high carbohydrate content, which ranges from 32 g per 100 g to 35 g per 100 g on a fresh weight basis, and from 80 g per 100g to 90 g per 100 g on a dry matter basis (Tivana, 2012). Cassava is low in lipid which range from 0.1% to 0.3% on a fresh weight basis and 0.1% to 0.4 and 0.65on a dry weight basis. This content is relatively low compared to maize and sorghum, but higher than potato and comparable to rice. The lipids are either non-polar (45%) or contain different types of glycolipids (52%). The glycolipids are mainly galactose-diglyceride (Emanuel *et al*., 2012)

2.10 Soybean and its Nutritional Values

Soybean (*Glycine max*) was first introduced in Tanzania in 1907; however, efforts to grow it in large scale began in 1947. Bossier (spherical and yellow) is the common variety of soybean in Tanzania and it is grown mainly in Mtwara, Lindi and Morogoro. Soybean is important in Tanzania as an alternative crop for correcting protein deficiency among the populations (Myaka, 1990). Soybean is a very promising crop as it contains all three macro-nutrients required for good nutrition, namely complete protein, carbohydrate and fat, as well as vitamins and minerals. Soybean is an abundant and economical source of protein. It can be used to increase protein content and improve the quality of cereal-based diets. Soybeans, however, contain high levels of antinutritional factors such as trypsin and chymotrypsin inhibitors and phytohaemaglutinins (Ramamani *et al*., 1996). Soybeans need to be processed to improve their nutrient availability. Industrial processes are designed to improve the food value of soybeans by inactivating the antinutritional factors and enhancing availability of nutrients (Carrao and Gontijo, 1994). Soybeans are usually not consumed directly, but processed into a large number of popular products (Damardjati *et al*., 1996). Raw soybeans do not promote growth due to antinutritional factors. Soaking and cooking under pressure makes soybeans a very nutritious source of protein (Liener and Tomlison, 1981).

Soybean protein is particularly valuable as it contains sufficient lysine that can serve as valuable supplement to cereal foods where lysine is a limiting amino acid. Its addition to a mixed diet, greatly improves the quality of the diet’s protein (Weingartner, 1987). The amino acid profile of soy protein is nearly equivalent in quality to meat, milk and egg protein. It is an inexpensive protein and oil source that could offer a sustainable solution to the problem of under-nutrition (Protein energy malnutrition, Anaemia, Vitamin A deficiency) (Laswai, 2006). Nutrition composition of soybean is as follows: 42% protein, 33% carbohydrates, 20% oil and 5% ash, on a moisture-free basis (Pearson, 1983). Soybean protein efficiency ratio (PER) ranges from 2.2 – 2.3 for both grits and flour compared to 2.5 for casein which is normally taken as the reference protein (control) in nutrition studies. PER is computed by dividing the growth rate of the study animal by the amount of protein consumed (Torun *et al*., 1981).

2.11 Peanut and its Nutrition Values

Peanut (*Arachis hypogaea*) is considered as one of the most concentrated foods because of their high protein and oil content. The protein content in peanuts ranges from 16 to 36 g per 100 g (Cherry and Ory, 1973; Dwivedi *et al*., 1990). Peanuts provide the greatest percentage of oil amongst legumes. The oil content of peanut seeds ranges from 36 to 56%. Lipids, being the major constituent of peanut kernels, is comprised of triglycerides and some phopshatides, glycolipids, unsaponifiables, phytosterols (sitosterol, campesterol, and stigmasterol), free fatty acids, antioxidants, tocopherols, and odor and flavor imparting higher hydrocarbons.

Peanuts contain fatty acids which are influenced by cultivar, maturity, storage, processing treatments and environmental conditions. Peanut oil contains more of oleic acid (47%) than linoleic acid (33%). Peanut oil, is lower in linoleic acid content (33% of total fatty acids) than corn oil (58%), safflower oil (79%) or mixtures of soybean and cottonseed oil (47%) (Shah, 2003). Peanut oil is used extensively as a salad oil and foods fried in it exhibit an excellent flavor and keeping quality. Peanut is easily digestible and serves as a good source of linoleic acid and other unsaturated fatty acids necessary for proper growth and nutrition (Shah, 2003). Peanuts are a rich source of some dietary minerals such as calcium, magnesium, phosphorous, potassium, and traces of iron, sodium, zinc, copper and manganese. Peanut is a poor source of fat-soluble vitamins A, D, and K, and only moderate source of vitamin E.

Traditionally, peanuts are sold raw or as paste in local markets or street food stores. Raw peanuts are preferred to peanut paste because they are slightly cheaper. Raw peanuts are traditionally roasted to develop an appealing roast flavor. The roasted peanuts are mixed with cereals and are ground together to form peanut–cereal composite flours (Mosha and Vincent, 2005). Peanuts are rich in nutrients commonly used to increase both protein and calories that are required to improve nutritional status of underweight children. Peanuts is a major product in the production of ready-to-eat food (Plumpy nuts®) used for addressing the problem of severe malnutrition in developing world, especially in India and sub-Saharan Africa (Dwivedi *et al.*, 1990).

2.12 Extrusion

Extrusion is a process whereby raw food materials are exposed to controlled condition of high temperature, pressure and moisture. The process is achieved by forcing the materials through a tapering screw shaft and passing through a die plate under high pressure accompanied by an injection of steam or water. During processing, the dough-like mixture is forced through a stationary metal tube or barrel by a rotating screw shaft. As this occurs, heat can be added in the form of steam and is also generated by the mechanical shearing of the turning screws and the friction of the barrel. As a result, very high temperature (>150C) can be reached (Harper, 1992).

Extrusion cooking is a popular means of preparing snacks and ready to eat food. In the extrusion processes, foods are cooked at high temperatures for a short time. Micro-organisms are largely killed, thereby extending the product shelf life (Filli and Nkama, 2007). Extruded products are formulated from mixtures of cereals, legumes and oil seeds and are completely pre-cooked for easy reconstitution and use. They can be fortified with vitamin and minerals after extrusion (Harper and Jansen, 1985).

Food industries have been applying extrusion technology to produce various products such as pasta, ready-to-eat cereals, meat analogs, flat breads and puffed snacks. Starchy materials from different kinds of cereals, legumes and tubers are commonly used in extrusion process (Nurtama and Lin, 2009). The use of extruders for food cooking has been expanding rapidly in the food industry due to their flexibility, high productivity, effectiveness, hygienic conditions and low operation costs (Riaz, 2000). Extrusion alters the nature of several food constituents, simultaneously with starches and proteins, by altering their physical, chemical and nutritional properties. High temperature short time (HTST) extrusion cooking technology has unlimited applications in processing of cereal based products. The pace of technological development has resulted in extruders which can process foods at moisture of less than 20%. The machines are affordable to middle and lower income people due to their low capital and operational costs requirements.

Extrusion cooking is characterized by the complex interplay of heat, mass, and momentum transfer in concert with the physical and chemical transformation of the food material and the conditions that prevail during extrusion (Rizvi *et al*,. 1995). Extrusion technology has been practiced for over 50 years in the production of breakfast cereals, snack foods and pet foods. Initially, its role was limited to mixing and forming macaroni as well as ready-to-eat cereal pellets. The extruder basically consists of a feeder/hopper where ingredient are placed, screws that rotate inside cylindrical barrel and a die that dictates the shape of the extruded products (figure 1). The food is mixed with water and compressed by the screws as they rotate and pushes the feed forward through the heated barrel. Due to the friction and the heat provided inside the barrel, the food is quickly heated. As the mixture advances along the barrel, pressure and heat buildup. This pressurized cooking transforms the mass into a thermoplastic “melt” (Berk, 1992). While the proteins suffer extensive heat denaturation the directional shear force causes alignment of the high molecular components (Berk, 1992). At the end of the barrel, the melt is forced out through the die. The sudden release of pressure leads to instant evaporation of some of the water. This causes puffing of the extrudates, resulting in a porous structure. The extrudates puffing or porous structure could be partially controlled by manipulating the melt temperature within the die.

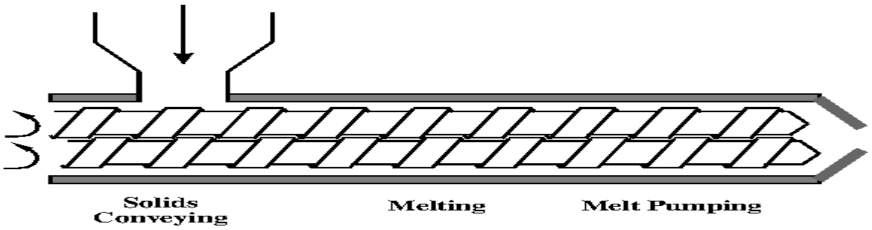

Figure 1: Double screw extruder

Extrusion process is used globally in which food materials are forced through a stationary metal to the production, modification, and improvement of quality of various food products such as ready to eat cereals, snacks, pet foods and or feed (Fill and Nkama, 2007). Extruded RUTF are formulated from mixtures of cereal, legumes and oil seeds and are precooked for easy reconstitution and use. Extruded RUTF is then fortified with vitamin and minerals.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Materials

The composite flakes were prepared from peanuts (*Arachis hypogaea*), soybeans (*Glycine max*), cassava flour (*Manihot esculenta*), vegetable oil and sugar. All materials were purchased from Morogoro municipal markets. Plumpy Nuts® was purchased from the Medical Stores Department.

3.2 Methods

3.2.1 Pre-processing of the raw materials

The fresh cassava roots were purchased from the market and processing began soon after the roots were delivered to the food processing laboratory. Cassava processing involved peeling, washing, soaking, chipping, drying and milling.

3.2.1.1 Peeling, washing and soaking

Peeling was done by the use of kitchen knife, whereas the fresh cassava roots were longitudinally and transversely cut to a depth corresponding to the thickness of the peel (skin and cortex). Then the peel was detached leaving the softer central part of the root. There after the peeled cassava roots were washed to remove that dirt remained on the surface and then soaked for overnight to get rid of mucilage.

3.2.1.2 Chipping, drying and milling

After washing and soaking the fresh cassava were chipped into thin chips using a motorized chipping machine (Intermek Engineering, Morogoro). After chipping, the cassava chips were sun dried until the moisture contents of less than 12% was attained then cassava chips were milled by using a commercial hammer mill (Intermek, Tanzania) to obtain fine flour (mesh size 0.6 mm).

3.2.2 Preparation of peanuts and soybeans

3.2.2.1 Sorting, cleaning and blanching,

Peanuts and soybeans were sorted and cleaned to remove dirt, stones, chaff, broken grains, spoilt grain and other foreign materials. Sorting was done manually. After sorting, the peanuts and soybeans were thereafter washed twice with distilled water. Soybeans were blanched by soaking them in boiling water for 15 minutes, this process was applied to soften the outer hulls and destroy the anti-nutritional factors in the soybeans.

3.2.2.2 Drying, milling and roasting

The blanched soybeans were sun dried until the moisture contents of less than 12%. Then, the soybeans were milled by using a commercial hammer mill (Intermek, Tanzania) to obtain fine flour (mesh size 0.6 mm). On the other hand peanuts were roasted in an open frying pan to develop the appealing roast flavor.

3.3 Product Formulation

The product was formulated in the laboratories of the Department of Food Science and Technology, Sokoine University of Agriculture. The ingredients were combined in proportions that provided the highest amino acid score possible according to the recommendation by FAO/WHO/UNU (1985). The composite product was formulated to contain the following nutrient composition: energy - 543.47 kcal per 100 g, protein - 13.04 g per 100 g of dry product and fat - 34.8 g per 100 g of product.

This composition was similar to that of F-100 or Plumpy Nut® (Nutriset, 2008). The composite flakes were formulated to provide the required amount of energy and micronutrients essential to support catch up growth of acutely malnourished children. The composition of the peanuts-soybeans-cassava composite product is presented in Table 3.

Table 3: Composition (g/100 g) of the peanuts-soybeans-cassava flakes

Ingredient	Composition
Peanuts	35
Soybeans	15
Cassava	30
Vegetable oil	13
Sugar	7
Total	100

3.4 Preparation of Extruded Products

The formulated product was processed into pre-cooked flour that could be reconstituted into porridge for child feeding. Extrusion of the composite product was carried out in a commercial twin-screw extruder (Model JS 60 D, Qitong Chemical Industry Equipment Co. Ltd, Yantai, China) (Photo. 1). Food moisture content was adjusted to 20%. The food was extruded using the following extrusion profile: Temperatures 138^{o}C (zone 1) and 126^{o}C (zone 2), main motor speed was set at 29.66 rpm and feeder speed rate of 8.79 rpm. The extruder consisted of two electrically heated zones one and two. Desired barrel temperature was maintained by circulating tap water. Temperature was controlled by inbuilt thermostat and a temperature control unit. After extrusion, the extrudates were dried at room temperature and thereafter milled to obtain fine flour.

Plate 1: Extruder machine used in extrusion

3.5 Product Fortification

After processing, the flakes were fortified with multivitamin and mineral premix and well mixed with a food-mixer (Intermek Iringa) to get homogenous mixture. The fortification levels per 100 g of the composite product were as per Table 4.

Table 4: Fortification of product as per 100 g of the composite product

Nutrients	Units	Per 100g
Vitamin A	µg	913.04
vitamin D	mg	16.304
vitamin E	mg	20
vitamin C	mg	53.26
vitamin B1	mg	0.598
vitamin B2	mg	1,804
vitamin B6	mg	0.598
vitamin B12,	µg	1.847
vitamin K	µg	20.978
biotin,	µg	65.217
Folic acid	µg	209.78
Pantothenic acid and	mg	3.097
niacin	mg	5.304
iron	mg	11.521
iodine	µg	100
sodium	mg	30
copper	mg	1.739
zinc,	mg	14.02
magnesium	mg	91.956
potassium,	mg	1110.86
calcium	mg	300
phosphorous	mg	300

3.6 Biological Assay

Rats (*Ratus norveigicus*) aged 21 days were weighed and housed in individual cages in a room with controlled temperature, relative humidity and light during day and night. During the experiment, rats were divided into two groups of 30 rats each. A group of 10 rats were fed a non protein diet. For each group, the rats were given the test diet for an acclimatization period of 4 days, and then they were weighed. One group received the control diet (Plumpy nuts®) while the second group was given the test diet (extruded peanuts-soybeans-cassava composite flakes). Rats had free access food and water throughout the feeding period. Body weights and food intakes were measured daily. Feces were collected in the last 10 days of the feeding study and used for determining fecal nitrogen. Another group of 10 rats received nitrogen free diet for 10 days. Feces were collected daily and used for determination of endogenous nitrogen excretion.

The collected feces were oven dried in a conventional oven set at 70°C for 48 hrs. The sample was then milled to fine powder prior to analysis. Data from the animal study were used to calculate PER, ADP and TPD (FAO/WHO, 1991).

PER = g of weight gain / g of protein consumed………………………………….. (1)

APD = I-F*100/I... (2)

TPD = I-(F-Fo)*100/I.. (3)

Where;-

I = Nitrogen intake of the test diet

F = Fecal nitrogen of the test diet

Fo = Fecal nitrogen of the control diet

3.7 Proximate Composition

Proximate analysis was used to determine the amount of protein, lipid, moisture, ash, total dry matter and carbohydrate in the composite product and the control. Proximate composition (dry matter, crude protein, crude fibre, crude fat and ash content) of the extruded flakes and the control were assayed according to the standard AOAC (1995) methods.

3.7.1 Dry matter

Determination of dry matter was done by oven drying method 925.10 (AOAC, 1995). Five grams of each sample were dried in a conventional oven set at 105°C for 24 hours to a constant weight. The samples were dried in pre-dried and pre-weighed crucibles. Dry matter was obtained by taking the difference between weight of the samples before and after drying. The difference obtained was expressed as percent dry matter with respect to original amount of the samples taken.

$$\%\ \text{Dry matter} = \frac{(C - B) \times 100}{A} \qquad \ldots\ldots(4)$$

Where: A = Weight of the sample taken (g)

B = Weight of crucible (g)

C = Weight of crucible and dry sample (g)

(C-B) = Weight of dry sample (g)

3.7.2 Ash

Determination of ash content was done according to AOAC (1995) method 923.03. One gram of dry sample was placed into a pre-heated and pre-weighed crucible and incinerated in a muffle furnace set at 550°C for 24 hrs until grey ash was obtained. Percent ash content was calculated by expressing in percentage the ratio of weight of ash (g) and weight of dry sample (g); whereby weight of ash was the difference between the weights of samples before and after incineration.

$$\text{Ash (\%DM)} = \frac{\text{Weight of ash (g)}}{\text{Weight of dry sample (g)}} \times 100 \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(5)$$

3.7.3 Crude protein

Crude protein content of the samples was determined by using the micro-Kjeldahl method 920.87 (AOAC, 1995). About 0.25 g of dried samples was weighed onto tired filter papers and quantitatively transferred into digestion tubes. About 10 g of catalyst (mixture of 10 g potassium sulphate, 0.5 g copper sulphate and 1.0 g titanium) were added into each tube containing the sample. Five ml of concentrated sulphuric acid were added to each tube. Samples were placed on Kjeldahl rack and heated slowly, then strongly, until the samples turned into clear green. The mixture was thereafter heated gently for one hour. After digestion, the digest was cooled and one tube at a time was mounted in the distillation unit (Foss Tecator, Model 2 200 Kjeltec Auto Distilling Unit, and Sweden). Thirty ml of double distilled water were added to the digest followed by 30 ml of 40% Sodium Hydroxide. The mixture was then distilled for 3 minutes. About 150 ml of the distillate were collected in a conical Erlenmeyer flask containing 20 ml of 2% Boric Acid. The distillate was thereafter titrated with 0.1N Hydrochloric Acid. Blank determination was carried out in the same manner using reagents without a sample.

Nitrogen content was calculated using the relationship:

$$\% \text{ Nitrogen } = \frac{1.4007 \times [titre(ml) - blank(ml)] \times Conc. of\ acid}{Weight\ of\ sample(g)} \quad \ldots\ldots\ldots\ldots\ldots\ldots(6)$$

Percentage crude protein was calculated from the percent nitrogen using the factor 6.25:% CP $= \%\ Nitrogen \times 6.25$.

3.7.4 Crude fiber

Crude fiber was determined by using AOAC (1995) official method 920.86. Ankom Fibre Analyzer (Model ANKOM 220, USA) was used for the determination of crude fibre. Exactly 1.0 g of sample was first digested by dilute sulphuric acid (0.125M H_2SO_4) for 30 minutes and washed three times with hot distilled water. The residues were then digested by dilute alkali (0.125M KOH) for another 30 minutes and washed three times by hot distilled water. Digested residues were dried in an oven set at 100^0C for 12 hours, then cooled in a desicator and weighed. The residues were then placed in a muffle furnace and ashed at 550^oC for 2 hours, then cooled and weighed. Total fibre content was taken as the difference between the weight of residues before and after ashing.

$$\% \text{ Crude fibre} = \frac{W_1(g) - W_2\,(g)}{W\ (g)} \times 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(7)$$

Where:

W_1 = Weight of sample residues before ashing (g)

W_2 = Weight of sample residues after ashing (g)

W = Weight of dry sample taken for determination (g)

3.7.5 Crude fat

Determination of total fat was done by Soxhlet Ether extraction method 920.85 (AOAC, 1995). Five grams of dry sample were weighed into extraction thimbles, plugged with cotton wool and assembled in the Soxhlet apparatus. One hundred ml of Petroleum Ether were used for continuous extraction of fat from the samples for eight hours. Petroleum Ether was thereafter recovered by evaporation. Pre-weighed cups containing fat were dried in a conventional oven set at 80^{o}C for 3 hours to evaporate the remaining Petroleum Ether. The cups with fat were cooled in desiccators for 1 hour and then weighed. Percent fat was calculated from the following formula:

$$\text{\% Crude fat} = \frac{Weight of\ crude\ fat(g)}{Weight of\ dry sample(g)} \times 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (8)$$

3.7.6 Carbohydrate

The carbohydrate content in the extruded flakes and Plumpy nuts® were calculated as a percent difference using the following relationship:

% Carbohydrate = 100 – (% protein + % crude fibre + % crude fat + % Ash).

3.7.7 Energy

Energy was calculated using the Atwater's conversion factors. Thus energy values were obtained by multiplying % fat by factor 9 while % protein and % carbohydrate were multiplied by a factor 4 (AOAC, 1990).

Energy content = [(%Carbohydrate x 4) + (%Fat x 9) + (%protein x 4)].

3.8 Minerals Composition

Five g of extruded flakes and Pumpy nuts® were incinerated and the ash obtained was used for mineral analysis. The ash was dissolved in 6 N HCl and left for 12 hours to allow extraction of minerals. The solution was filtered quantitatively into a 100 ml volumetric flask. Concentration of Calcium, Iron, Zinc, Magnesium, Potassium, Phosphorous, Lead, Sodium, Selenium and Copper in the sample were determined by using UNICAM Atomic Absorption Spectrophotometer (Model 919, Cambridge, U.K). Standards were set at highest sensitivity when reading each corresponding lamp and the wavelength set. Zeroing was done after setting on flame and setting the wavelength as per Table 5.

Table 5: Wave length of different minerals

Minerals	Units	Wave length (λ)
P:	nm	884
Se	nm	196
Pb	nm	217
Mg:	nm	285.2
K	nm	766.5
Na	nm	589
Ca	nm	422
Fe	nm	248
Cu	nm	324
Zn	nm	213

Mineral concentrations were calculated and expressed in mg/100 g on dry weight basis using the relationship:

$$\text{Mineral concentration (mg/100g)} = \frac{GR}{1000ml} \times \frac{100ml}{SW} \times DF \times 100g \ \ldots\ldots\ldots\ldots\ldots\ldots(9)$$

Where;

GR = Absorbance

SW = weight of dry sample

DF = Dilution factor

3.9 Sensory Evaluation

3.9.1 Preparation of gruels for sensory evaluation

To reconstitute the flakes for feeding, boiling water was added to the extruded composite food and boiled for 5 minutes to soften the flakes for easy mastication. The flakes were reconstituted few minutes before sensory evaluation was performed.

Sensory evaluation was done using a surrogate panel of 40 semi-trained panelists (SUA students). The panel consisted of 22 males and 18 females aged 21 and 43 years. Sensory evaluation was conducted to determine organoleptic attributes namely colour, aroma, taste, texture (mouth feel), appearence and overall acceptability. A 5-point Hedonic scale (Larmond, 1997).was used with 5 being strongly like; 4 was moderately like;3 was neither like nor dislike while 2 was moderately dislike and 1-was strongly dislike.

3.9.2 Sensory evaluation and acceptability

The gruels were placed in identical cups coded with three digit random numbers. Samples were presented to the panelists in a cool environment. Sensory evaluation was conducted in the laboratories of the Department of Food Science and Technology, Sokoine University of Agriculture. Panelists were asked to test each product at a time and express their degree of preference in relation to the following sensory attributes: colour, aroma, taste, texture (mouth feel), appearance and overall acceptability. The degree of preference was converted into numerical scores ranging from 1 to 5, whereby 1 was strongly disliked and 5 were strongly like. After testing a product, panelists rinsed their palate before testing the next product. Sensory evaluation procedure was carried out at between 10:30 am to 12:30 pm.

3.10 Statistical Analysis

Data were analyzed using General Linear Model (GLM) and Mixed Model procedures of Statistical Analysis System (SAS, 9.2; 2002). The significant differences at 5% between treatments were compared using the PDIFF option of SAS

(9.2). Covariance analysis was used to correct for the variation in initial body weight for animal performance. The models used were as follows:

3.10.1 Model: Animal performance and feed evaluation

The first model was feed evaluation focusing on weight gain, food consumption, protein efficiency ratio, true digestibility and apparent digestibility which included the fixed effect of diet types as treatments and random errors.

$Y_{ik} = \mu + A_i + e_{ik}$…………………………………………………………………...……………………… (10)

Y_{ijk} = measurement of an individual animal and feed evaluation

μ = Overall mean

A_i = Effect of i^{th} dietary treatments

e_{ik} = random error

3.10.2 Model: Proximate and mineral analysis of diets

The model for proximate analysis included the fixed effect of diet and the random error.

$Yik = \mu + Ai + eik$……………………………………………………………....…. (11)

Y_{ik} = Proximate analysis results

μ = Overall mean

A_i = Effect of i^{th} dietary treatment

e_{ik} = random error

3.10.3 Model: Diet sensory quality and acceptability

In analyzing the data, the model for diet sensory quality and acceptability included the fixed effects of dietary treatment, panelist's sex and age, and the interaction of main effects and random errors.

$Yik = \mu + Ai + eik$..(12)

Y_{ik} = Respondent's view

μ = Overall mean

A_i = Effect of i^{th} dietary treatment

e_{ik} = random error

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Quality of the Composite Product

Table 6 shows the weight gain, protein efficiency ratio and the amount consumed by the rats receiving the test diet (PSC) and control (PN). Rats on the test diet gained significantly ($p < 0.05$) higher weight compared to the rats on control diet. This was a reflection of the higher amount of food which was consumed by the rats on test diet. Weight gain is influenced by food intake and nutrient density of the food. According to Mosha and Benink (2004), low protein diet or in balance dietary protein suppresses food intake. In this study rats fed on PSC gained an average weight of 1.18 g per day while those fed on PN gained an average weight of 1.03 g per day. Feed consumption was 5.53 g per day and 5.01 per day for the test diet (PSC) and control diet (PN), respectively. According to FAO/WHO (1991), rats have higher requirement for some amino acids when compared to humans. Since both foods met the requirements for rat growth, this food would also be suitable in supporting catch up growth of acutely malnourished children.

Protein efficient ratio (PER) determines the effectiveness of the protein to support growth of the test animal. Protein efficiency ratio is taken as a ratio of weight gain by an animal to the protein intake from the food (FAO/WHO, 1991). High protein efficiency ratio suggests high weight gain due to protein content of food. Table 6 shows PER for two groups of animals fed on the test diet and the control. There was no significant ($p > 0.05$) difference in the PER among the rats fed on the test diet

(PSC) and those fed on the control diet (PN). In this study, both diets the control (PN) and the test (PSC), had protein efficiency ratio that was very close to the casein which is reference protein with efficiency ratio of 2.5 (Torun *et al*., 1981). PER of the test diet was 2.32 while that of the control (Plumpy nuts®) was 2.34. Protein efficiency ratio of a food reflects its biological value, since both basically measure protein retention by body tissues. Plant proteins, because of their incomplete nature, generally yield PER values which are lower than those of animal foods.

Table 6: Weight gain, protein efficiency ratio and food consumed by rats consuming the test diet and the control diet

Attribute	PSC	PN	P - value
FC	5.53±1.69	5.01±1.68	0.0001
WTG	1.18±0.28	1.03±0.27	0.0001
PER	2.32±0.02	2.34±0.02	0.3373

PSC= Peanuts-cassava-soybean, PN= Plumpy nuts®, FC= Food consumed, WTG= Weight gain and PER=Protein efficiency ration

4.2 Digestibility

Digestibility is a measure of the efficiency of digestion and absorption of various nutrients present in food. Digestibility is considered as one of the important determinants of food quality. Digestibility serves as the measure of dietary quality and nutrient availability and as a basis to estimate dietary needs and requirement (FAO, 2013). Table 7 presents the digestibility of the test diet (PSC) and the control (PN). There were significant differences ($p < 0.001$) in the apparent and true protein digestibilities of the two products. True protein digestibility of the test diet was 93.99% while that of the control diet (PN) was 83.13%. The true protein digestibility of the test diet (PSC) was therefore higher ($p < 0.001$) than that of the control diet. High digestibility of protein in PSC could be due to presence of soybeans in the composite product. Mensa *et al*. (2001) and Edem *et al*. (2001) reported true protein digestibility of cowpea-soybean-maize weaning food and cassava-soybean composite product to be as high as 91%. Soybean is therefore highly digestible.

Apparent protein digestibility (APD) is the ratio of the difference between the ingested nitrogen and fecal nitrogen to the ingested nitrogen, expressed as a percent. This measure, however, is affected by the assay conditions and is therefore variable and subject to errors. APD is an indication of amino acid availability in the food and therefore it is a predictor of true digestibility of food (FAO/WHO, 1991). Apparent protein digestibility of the test diet (PSC) was 90.68% higher than that of the control diet (PN) which is 79.05%. (Table 7).

Table 7: True digestibility and apparent protein digestibility of the test and control diet

Attribute	PSC	PN	P - value
APD	90.68 ±0.19	79.05±0.19	0.0001
TPD	93.99 ±0.16	83.13± 0.16	0.0001

APD= Apparent protein digestibility, TPD= true protein digestibility

True digestibility of protein which makes allowance for the nitrogen in the faeces of non-dietary origin (metabolic nitrogen) is subtracted from the total faecal nitrogen and therefore always greater than apparent digestibility (FAO/WHO, 1991). True protein digestibility is a key food quality index because it indicates whether the amino acids present in a food protein would be digested and become available for utilization by the body (Mosha *et al*., 2005). Low protein digestibility limits the amount of amino acids in a food that can be absorbed into the body, and can therefore adversely affect growth (Mosha *et al*., 2005). Therefore having true protein digestibility greater than 82% suggests that, the protein and amino acid in the test diet (PSC) and the control diet (PN) would be available for utilization by the body when the foods are consumed. They therefore have a good potential to support growth. True digestibility is a superior measure for determining the amino acid that are absorbed from the gut and therefore gives a better indication of protein quality than the apparent digestibility.

4.3 Proximate Composition

4.3.1 Dry matter

Table 8 shows the dry matter contents of the test diet and the control (PN). The control diet had dry matter of 97.45 g per 100 g higher than that of the test diet (94.54 g per 100 g). These values corresponded with moisture values of 2.55% (PN) and 5.46% (PSC). The moisture levels were less than 7% similar to values reported by Filli *et al*. (2010) in extruded cereals. The moisture contents of the composite diet (PSC) and that of the control (PN) were below 10%. Such low moisture contents prevent microbial activity and extend the shelf life of the products (Kikafunda *et al*., 2006). The low moisture values of the products suggested that, they had good keeping quality.

4.3.2 Ash

Ash content was 5.16 g per 100 g and 3.45 g per 100 g for PSC and PN, respectively. Ash content was higher ($p < 0.05$) in the test diet PSC than in the control diet (PN) (Table 8). This implied that, PSC could be richer in inorganic nutrients than the PN. The level of ash in food is an important nutritional indicator for mineral density but also a quality parameter for contamination, especially with foreign matter (Fennema, 1996).

4.3.3 Protein

There was a significant difference ($p < 0.05$) in crude protein content between the test diet (PSC) and the control (PN). The protein content of PSC was 14.28 g per 100 g while that of PN was 12.1 g per 100 g (Table 8). Soybeans contain 40 – 45 g of protein per 100 g of the dry grain (Yagasaki *et al*., 1997). Inclusion of large amount of soybean flour into the products resulted in higher protein content. Similar results using different type of legumes were reported by Mosha and Vicent (2005). Soybeans significantly increased the protein content in the composite mixtures. Protein is an essential macronutrient for the growth and maintenance of the body (FAO/WHO/UNU, 1985).

The protein contents of the test diet (PSC) (31.78 g per 1 000 kcal) and that of the control diet (PN) (26.96 g per 1 000 kcal) were higher than the levels recommended for moderately acutely malnourished children (26 g per 1 000 kcal) (Golden, 2009). Golden (2009) also reported that, F-100 contains 28 g per 1 000 kcal; in which protein provide 11.2% of energy which is sufficient for rapid catch up growth. The protein content of the test diet (PSC) which was 31.78 g per 1000 kcal could provide energy value of 12.7 % and thus was suitable for supporting rapid catch up growth. Conversely, the control diet (PN) with protein content of 26.96g per 1000 kcal l could provide energy of 10.78% was closer to the recommended protein intake of 26 g per 1 000 kcal of food.

4.3.4 Carbohydrate

There was no significant difference ($p < 0.05$) between carbohydrate content of the test diet (PSC) and the control (PN) (Table 8). A carbohydrate is an important source of energy in diet. It includes sugars or polymers of sugar such as starch that can be hydrolyzed to simple sugars. Carbohydrate containing food is important vehicle for protein, vitamins, minerals and other food components such as phytochemicals and antioxidants (Bowman and Russel, 2001).

4.3.5 Crude fibre

There was statistical difference ($p < 0.05$) in the crude fibre content between the test diet and the control (Table 8). The fiber content of test diet (PSC) was 22.89 g per 100 g while that of the control diet (PN) was 26.07 g per 100 g. Fibre forms an important dietary component for children and adults as it prevents constipation, overweight, cardiovascular diseases, diabetes and colon cancer (Whitney *et al*., 1990). For children, however, dietary fiber is recommended to be low so as to increase energy density. According to Codex Almentarious Comission (CAC/GL 8 – 1991) (FAO/WHO, 2013) recommendation, fiber intake for children should not exceed 5 g per 100 g of food on dry weight basis. Both the test diet (PSC) and the control diet (PN) had fiber contents that were higher than the amount recommended by the Codex Almentarious Comission. High fibre content reduce energy intake through a suppressing effect on appetite, and may increase fecal losses of energy due to reduced absorption of fat and carbohydrate. Children under treatment for severe acute malnutrition with F-100 receive a diet with no dietary fiber (Michaelsen *et al*., 2009). Therefore intake of dietary fiber for children with moderate malnutrition should be as low as possible due to high energy needs.

4.3.6 Crude fat

There was no significant difference ($p < 0.05$) in fat contents between the two products. Both PSC and PN had fat content of 32.27 g per 100 g and 33.37 g per 100g respectively (Table 8). Fats enhance the taste and acceptability of foods. Dietary lipids provide essential fatty acids and facilitate absorption of fat-soluble vitamins (FAO/WHO, 1994b). Fats also increase the energy density of food. However, too much fat is not recommended as it dilutes the density of protein and micronutrients per 100 kcal (Innis, 1991). Children with moderate malnutrition, especially those who are moderately wasted, have increased needs for energy for catch-up growth. They thus require a diet with high energy density. In this study, the test diet (PSC) had a fat content of 32.27 g per 449.35 kcal equivalent to 64.63% of energy from fat while the control diet (PN) had 33.37 g per 448.77 kcal equivalents to 66.92% of energy from fat. The energy values from fat are higher than that of F100 which is 50% and RUTFs which are between 50% and 60%. F-100 and RUTF are foods recommended for treatment of children with severe malnutrition (Michaelsen *et al*., 2009). Therefore a diet with high fat content is likely to be beneficial for acutely malnourished children. In light of the above, the test diet (PSC) was therefore good for supporting children with acute malnutrition due to its high energy content.

Table 8: Proximate compositions (g/100 g) and energy density (kcal/100 g) of extruded Peanuts-soybeans-cassava composite product and Plumpy nut®

Variable	PSC	PN	P – value
Dry matter	94.54±0.10	97.45±0.10	0.0036
Ash	5.16± 0.20	3.45± 0.20	0.0187
Protein	14.28±0.20	12.1± 0.20	0.0096
Carbohydrate	25.45± 2.70	25.01±2.70	0.4985
Fibre	22.89±0.40	26.07±0.40	0.0257
Lipid	32.27± 0.50	33.37± 0.50	0.2795
Energy	449.35± 13.96	448.77±13.96	0.5152

4.3.7 Energy density

High energy density in therapeutic foods has been pointed out as a major cause of fast growth and well nourishment among undernourished children (Dewey and Brown, 2003). Enrichment of cassava-based formulations with soybeans and peanuts significantly improved their energy densities (Table 8). The energy density is one of the most important qualities of foods for wasted children. If the energy density is too low and food is bulky, then the child would not be able to get enough calories (Michaelsen *et al.*, 2009). Energy density is most important for children with wasting, as they have an increased energy need for catch-up growth. The most important factor influencing energy density is the fat content, as the energy density of fat (9 kcal per g) is more than double that of protein and carbohydrate (4 kcal/g) (Michaelsen *et al*., 2009). A study of 18-month old malnourished children in Bangladesh which compared a diet with energy density of 92 kcal per 100 g with a diet containing energy density of 147 kcal per 100 g reveled that, there was an increase in energy intake by 50% in the group receiving energy–dense diet (Michaelsen *et al*., 2009). Thus, increasing energy densities to above 1.0 kcal/g resulted in increased energy intake among malnourished children (Michaelsen *et al*., 2009). Michaelsn *et al*. (2009) also reported that, ready-to-use therapeutic foods (RUTFs) are very effective in treating severely wasted children. The test diet (PSC) with an energy density of 449.35 kcal per 100 g and the control diet (PN) with energy density of 448.77 kcal per 100 g would therefore provide sufficient energy to enhance catch up growth in acutely malnourished children.

4.4 Mineral Composition

4.4.1 Phosphorous concentration

Table 9 shows that, the concentration of phosphorous was higher in the PN (1 814.29 mg per 1 000 kcal) than in the test diet (952.04 mg per 1 000 kcal). According to Golden (2009) recommended intake of phosphorous for moderately acute malnourished child is 900 mg per 1 000 kcal. Phosphorous concentration in the control diet 1 814.29 mg per 1 000 kcal (PN) and the test diet (PSC) (952.04 mg per 1 000 kcal) were higher than the recommended amount 900 mg per 1 000 kcal. According to Michaelsen e*t al*. (2009), absorption of dietary phosphorus is relatively high (55 to 70%), independently of dietary composition, and does not appear to be up-regulated at low intakes. Phosphorous in legumes which is plant material is in phytate form, which is resistant to digestion unless enzymatically degraded by phytase. Thus, phosphorus from phytate is only absorbed to a minor degree under normal conditions. Phytate fraction of phosphorous is normally discounted from calculation of total phosphorous intake because it is usually not bioavailable (Michaelsen *et al*., 2009). Phosphorous is important component of bone and tissue growth and is also required for various metabolic components such as acid-base balance. It is also a vital part in energy utilization and transfer. Phosphorous compounds are both directly and indirectly involved in all major physiological functions and are also a component of a large number of co-enzymes and the structure of nucleic acids (DNA) (FAO/WHO/UNU, 1985).

4.4.2 Calcium content

The levels of Calcium in the test diet (PSC) and the control diet (PN) were statistically different ($p < 0.05$) (Table 9). Calcium concentration was higher (713.424 mg) in PSC than in the PN product (309.62 mg). According to Golden (2009), supplementary food for moderately acute malnourished children should provide calcium concentration of 840 mg per 1 000 kcal. This concentration was higher than the calcium levels observed in the control diet (689.93 mg per 1 000 kcal). However, the calcium concentration in the PSC (1587.68 mg per 1 000 kcal) was higher than the recommended (840 mg per 1 000 kcal) levels but was within the calcium: phosphorous ratio of 0.7 to 1.3 that is recommended for acutely malnourished children (Golden, 2009). Calcium is essential for infants and young children for building up bones, teeth, muscles and nerves functioning, blood clotting and for immune function (Whitney *et al.*, 1990). Most moderately malnourished children need a diet that is rich in calcium to allow restoration of normal bone density and maintenance.

4.4.3 Magnesium content

Magnesium concentration in PSC (363.30 mg) was higher compared to the concentration (75.28 mg) in the control diet (PN) (Table 9). Magnesium is vital for the activity of more than 300 enzymes and plays important roles in neurochemical transmission and muscular excitability (Laires *et al.*, 2004). There are no recommended levels of Magnesium intake for acutely malnourished children. However, the metabolic demand for magnesium for acutely undernourished children is presumed to be higher than the amount recommended for malnourished children. Magnesium content of PSC product was 808.5 mg per 1 000 kcal higher than magnesium 300 mg per 1 000 kcal recommended for malnourished children. According to Golden (2009), if the diet has a high fiber or phytate content or if diarrhea is anticipated, the intake of magnesium should be increased. Magnesium is required for increased skeletal growth especially in children.

4.4.4 Iron content

Table 9 shows iron concentrations of the test diet (PSC) and the control (PN). PSC had iron concentration of 30 mg per 449.35 kcal while PN has iron concentration of 7.5 mg per 448.77 kcal of the food. The concentration of iron in PSC product was higher ($p < 0.05$) than that of the control product. According Golden to (2009), the recommended iron intake for moderately acute malnourished children is 18 mg per

1 000 kcal. Of all the nutrients that are added to rehabilitation foods for malnourished children, iron has received the most attention. The iron content of PSC product (66.763 mg per 1 000 kcal) was higher than the amount (18 mg per 1 000 kcal) recommended for acutely malnourished children. Iron absorption is determined by the amount of body store of iron, absorption rate increase when body stores are diminished. An average absorption of heme iron from meat containing meal is 25% while during iron deficiency absorption is about 40%. Non heme iron has a lower rate of absorption (2 – 10%) depending on the balance between iron absorption inhibitors and iron absorption enhancers present in the diet. Iron inhibiting factors includes phytates, polyphenols, calcium and phosphate (Michaelsen *et al.,* 2009). PSC product contains high levels of calcium and phosphorous. Food with high levels of iron inhibitors need to be prepared with at least 25 mg of ascorbic acid since ascorbic acid is iron absorption enhancer. Iron is vital for transporting oxygen in the bloodstream and for preventing anemia. It also serves as an integral part of important enzyme systems in various tissues and as a transport medium for electrons within cells. For growing children, the need for iron increases with rapid growth and expansion of blood volume and muscle mass (Russell, 2001). Dietary iron deficiency is the most important cause of nutritional anemia (Hallberg and Hulthen, 2000).

4.4.5 Copper content

The concentrations of Copper in the control (PN) and the test diets (PSC) were 1.310 mg and 1.740 mg per 100 g of food, respectively (Table 9). Concentration of copper was higher ($p < 0.05$) in the PSC than in the control (PN). Copper content of the test diet (3.87 mg per 1 000 kcal) was higher than the recommended intake of 890 µg per

1 000 kcal (0.89 mg per 1 000 kcal) for moderate acutely malnourished children (Golden, 2009). Copper is essential micronutrient in the absorption and utilization of iron during hemoglobin and myoglobin biosynthesis and forms part of several enzyme systems (King and Burgess, 1993). Increased dietary intake of Copper along with iron in the supplementary foods may have a beneficial effect of enhancing iron uptake and utilization. Malnourished children who receive adequate copper are less likely to get infections during recovery. Effects of copper deficiency can include anemia, low numbers of white blood cells, osteoporosis and defects in connective tissues leading to skeletal problems (King and Burgess, 1993).

Table 9: Mineral composition (mg/100g) of extruded peanuts-soybeans-cassava composite flakes and Plumpy nut® products

Variable	PSC	PN	P - value
P	427.80± 0.00	814.2± 0.00	0.0001
Se	8.235±0.01	5.88±0.01	0.0001
PB	1.023±0.01	0.79±0.01	0.0001
Cu	1.740±0.20	1.31±0.20	0.0001
Fe	30.00±0.20	7.50±0.20	0.0001
Zn	12.14±0.01	8.40±0.01	0.0001
Ca	713.42±0.20	309.62±0.20	0.0001
Mg	363.30±0.40	75.28±0.40	0.0001
K	703.95±0.10	819.92±0.10	0.0001
Na	118.60±0.50	57±0.50	0.0001

4.4.6 Zinc content

Concentration of zinc in the test diet (PSC) was 12.14 mg per 449.35 kcal while the concentration of zinc in the control diet (PN) was 8.40 mg per 448.77 kcal of food.

(Table 9). Zinc concentration in the test diet (PSC) (27.01 mg per 1 000 kcal) was higher than the intake of 20 mg per 1 000 kcal recommended for moderately acute malnourished children while that of the control diet (PN) was low (18.72 mg per 1 000 kcal). When children are gaining weight rapidly and are sequestering nutrients into tissue, their mineral intakes not only of zinc but also of copper and other nutrients usually increase (Golden, 2009). Zinc is required as a component of more than 200 enzymes and as a structural component of many proteins, hormones, hormone receptors and neuropeptides. Zinc also plays a central role in the immune system, affecting a number of aspects of cellular and humoral immunity (Shanker and Prasad, 1998). In children, zinc deficiency has been shown to lead to poor growth (Brown *et al*., 2002), impaired immunity, increased morbidity from common infectious diseases and increased mortality (Sazawal *et al*., 1998).

4.4.7 Selenium content

Selenium content of the test diet (PSC) was 8.235 mg per 449.35 kcal (18.326 mg per 1 000 kcal) higher than 5.882 mg per 448.77 kcal (13.106 mg per 1 000 kcal) of the control diet (PN) (Table 9). According to Golden (2009), the recommended Selenium intake for acutely malnourished children is 55 µg per 1 000 kcal which is equivalent to 0.055 mg per 1 000 kcal. Selenium contents of both test diet (PSC) (18.326 mg per 1 000 kcal) and the control diet (PN) (13.106 mg per 1 000 kcal) were higher than the recommended intake of 0.055 mg per 1 000 kcal. Selenium is an important anti-oxidant that protects the body against oxidative stress. It is also part of gluthatione peroxidase which is an important antioxidant enzyme (Orisakwe *et al.*, 2009).

4.4.8 Lead content

Lead content of the test product (PSC) was 1.02 mg per 449.35 kcal while the control diet (PN) was 0.79 mg per 448.77 kcal (Table 9). According to Golden (2009), there are no recommended levels of intake for lead for acutely malnourished children. Excessive intake of lead has been reported to be toxic and teratogenic. Excessive intake of lead impairs synthesis of hemoglobin, causes dysfunction of kidney, joint, cardiovascular system, and reproductive system and causes chronic damage to the central nervous system (Duruibe *et al*., 2007). It is therefore important to keep the concentration of lead in child foods as low as possible. It is recommended that, the concentration of lead should not exceed 0.01 mg per gram of food so as to ensure safety of the foods for malnourished children (Duruibe *et al*., 2007). The level of lead per 1 g of food for both test diet (PSC) and control diet (PN) were 0.01 and 0.0079 mg respectively; these levels are within the acceptable range of 0.01 mg per gram of food.

4.4.9 Potassium content

Results in Table 9 show that, Potassium concentration in the control diet (PN) (819.92 mg per 448.77 kcal) was higher ($p < 0.05$) than the concentration in the test diet (PSC) (703.95 mg per 449.35 kcal). The amount of potassium in F-100 is 2,400 mg per 1 000 kcal. This is adequate to support rapid growth and body Potassium in severely malnourished children (Golden, 2009). The recommended Potassium intake for acutely malnourished children is 1 600 mg per 1 000 kcal (Karakochuk, 2010). Potassium content of the test diet (PSC) (1 566.6 mg per 1 000 kcal) was slightly lower than the recommended amount (1 600 mg per 1 000 kcal), while that of the control diet (PN) (1827.03 mg per 1 000 kcal) was higher than the recommended (1 600 mg per 1 000 kcal) for malnourished children. Potassium forms a major electrolyte component in human body. It assists in metabolic process of various nutrients such as fats, proteins and carbohydrates. Potassium is also of great value in extracting the energy out of nutrients consumed by man. Potassium also ensures good health for heart as well as kidneys (Michaelsen *et al.*, 2009).

4.4.10 Sodium content

PSC contained higher ($p < 0.05$) concentration of sodium (118.6 mg per 449.35 kcal) than the PN (57 mg per 448.77 kcal). The recommended sodium intake for acutely undernourished children is 550 mg per 1 000 kcal (Golden, 2009). The level of sodium in the test diet (PSC) (263.94 mg per 1 000 kcal) was lower than the amount recommended 550 mg per 1000 kcal (Golden, 2009). Sodium content of the test and control diets were lower than the 550 mg per 1 000 kcal recommended for acutely malnourished children. Sodium is the main electrolyte in the extracellular fluid. It is beneficial in the diet as it adds taste and improves the acceptability of the diet. Sodium is unlike other nutrients its requirements decreases considerably instead of increasing during malnutrition. High concentrations of sodium should not be given to children who have developed kwashiorkor or who are severely malnourished. It would be appropriate to design diets for moderately malnourished children with low sodium content which if consumed by severely wasted children they would not cause harm. Further, high sodium concentration would increase renal solute load that will need to be excreted and thus increases the water requirement and increase the risk of dehydration.

4.5 Sensory Evaluation and Acceptability

Table 10 shows the results for sensory evaluation and acceptability of the extruded PSC composite product and the control (PN). Sensory evaluation of food products is important for determining consumer acceptability (Samuel *et al*., 2006). Panelists detected significant ($p < 0.05$) differences in colour between the test diet and the control. Food color strongly influences acceptability. In this study the control diet (PN) was significantly ($p < 0.05$) more preferred to the test diet in respect to colour. In terms of aroma, both products were equally appealing in smell and taste ($p > 0.05$). This similarity in smell and taste could be due to presence of peanuts in both products.

Table 10: Sensory attributes of the peanuts-soybean-cassava (PSC) gruel and Plumpy nut®

Attribute	PSC	PN	P - value
Appearance	4.08±0.16	4.25±0.16	0.4388
Colour	3.69±0.19	4.27±0.19	0.0357
Taste	4.36±0.23	4.24±0.23	0.7072
Mouth feel	3.52±0.33	4.27±0.33	0.1187
Smell	3.85±0.23	4.13±0.23	0.3834
Overall acceptability	4.14±0.19	4.60±0.19	0.1036

PSC= Protein soybean cassava, PN=Plumpy nut

Table 10 also indicates that, the test diet (PSC) and the control (PN) had similar appearance, though the control was ranked slightly higher ($p > 0.05$) than the test diet. The control diet (PN) had significantly ($p < 0.05$) superior texture (mouth feel) compared to the test diet (PSC). This could be due to the fact that, the test diet (PSC) was served as gruel made from very fine flour while the control was served as a crunchy bar which was more crispy in the mouth. Texture is an important sensory attribute that influences customer selection and acceptability of a product. Texture is influenced by physical characteristics of the flour such as particle size but also by fiber content. It was observed in this study that, grinding the extrudates after extrusion resulted in very fine textured flour that made cooked gruel to be very smooth. Except for the colour, the test diet was similar to the control (PN) in all other attributes namely appearance, taste, mouth feel and smell. The test diet was just as good as the control diet and was equally acceptable to the consumers.

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMENDATIONS

5.1 Conclusions

This study showed that, peanuts-soybeans-cassava composite flakes could meet the recommended nutritional requirements for therapeutic food, hence, suitable for rehabilitating under-nourished children. Some nutrients in the test diet ware higher than those of the control product. The test product had high true digestibility value of 93.99% which made it suitable supplemental food for children. Based on true digestibility, PER, proximate and mineral composition, it can be concluded that the product would be able to support optimal growth of undernourished children. Based on the result of this study, it is possible to formulate and manufacture extruded ready-to-eat therapeutic food of high nutrient density by combining locally available foods such as peanuts, soybeans and cassava. The test product was just as good as the control diet (PN) in terms of colour, mouth feel, taste and overall acceptability. It is Therefore the product has the potential to be used as Plumpy nut® substitute in the management of acute malnutrition in children.

5.2 Recommendations

i. Findings of this study clearly indicated the potential of cassava in the production of ready-to-eat composite foods for addressing the problem of under-nutrition. Thus there is a need to promote the use of cassava in the formulation and production of ready-to-eat fortified supplementary foods.

ii. Since under-nutrition problems are still rampant in Tanzania, and the Government uses her hard earned income to import Plumpy nuts®, it is important to promote the use of the test diet (PSC) in the management of acutely malnourished children instead of relying on the Plumpy nuts® which is imported and expensive.

iii. It is recommended based on the study results that, more research should be conducted to determine the shelf life of the PSC under various weather conditions.

iv. Further study is also needed to determine the levels of vitamins, ant-nutritional factors and microbial quality of the test diet (PSC).

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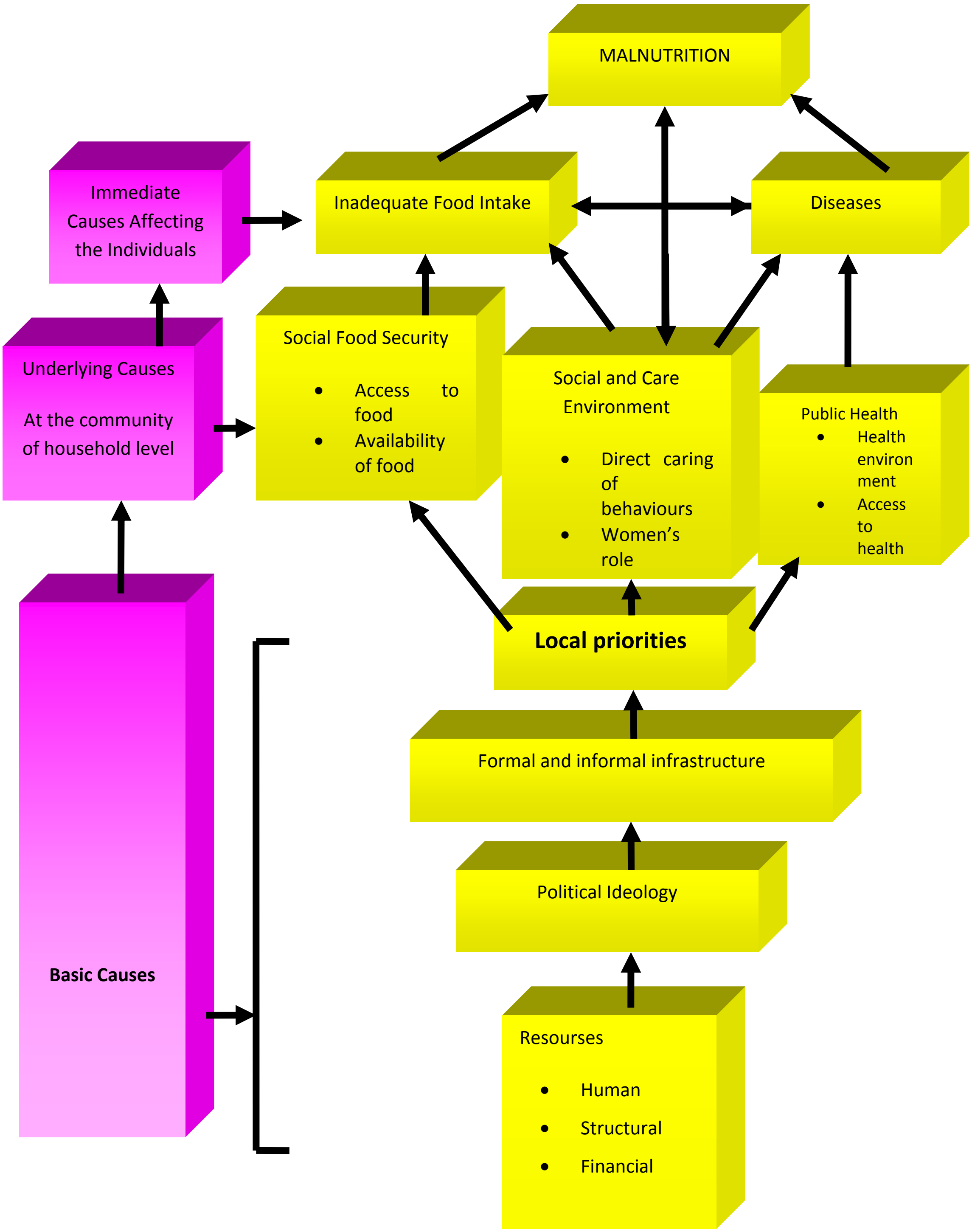
APPENDICES

Appendix 1: Conceptual framework of malnutrition



Appendix 2: Sensory evaluation form

Name………………………

Age…………

Sex…………..

Date…………….

Please choose the term that best reflects your attitude towards the product by writing a number under the product code.

Key: 1- Strongly dislike, 2- Moderate Dislike, 3- Neither like nor dislike, 4- Moderately like, 5- Strongly like

Sample	**Appearance**	**Smell**	**Colour**	**Taste**	**Mouth feel (texture)**	**Overall acceptability**
123						
456						

Comments 123………………………………………………………………..

Comment 456……………………………………………………………………….