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# DEVELOPMENT OF A NUTRIENT DENSE COMPLEMENTARY PORRIDGE FLOUR FROM LOCALLY AVAILABLE FOODS

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**JULY, 2017.**

## DECLARATION

I Mary R. Marcel, declare that this thesis is my original piece of work and has not been published or submitted to any university or institution for the award of a degree.

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This thesis has been submitted for examination with approval of the following supervisors;

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# DEDICATION

*This work is dedicated to my mother and relatives for their love and prayers.*

## ACKNOWLEDGEMENT

Before all, my greatest appreciation goes to God Almighty who created me, gave me opportunity to realize this dream, because it is not by my own power or might that I have been able to do this work, but it is by His Spirit and grace.

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**Mary R. Marcel**

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## LIST OF ABBREVIATIONS

**SAPO:** Soybeans, Amaranth grains, Pumpkin seeds and Orange fleshed sweet potato

**SAPOF:** Flour samples

**SAPOP:** Porridge samples

**SOS:** Soybeans, Orange fleshed sweet potato and Sorghum

**SMGM:** Soybeans, Maize, Groundnuts, and Millet

**TFNC:** Tanzania Food and Nutrition Centre

**UNICEF** United Nations Children Fund

**TDHS:** Tanzania Demographic and Health Survey

**RAC:** Reaching Agent of Change

**NRC:** National Research Council

**IPC:** International Potato Centre

**TAHEA:** Tanzania Home Economic Association

**OFSP:** Orange fleshed sweet potato

**ICDS:** Integrated Child Development Scheme

**HKI:** Hellen Keller International

**IVPD:** In vitro Protein Digestibility

**QDA:** Quantitative Descriptive Analysis

**PC:** Principal Component

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## Abstract

Prevalence of childhood malnutrition in Tanzania is still high despite the numerous interventions that have been carried out to solve this problem. This has also been contributed by poor complementary feeding practices. This study developed a nutrient dense complementary porridge from soybeans, amaranth grains, pumpkin seeds and orange fleshed sweet for use in complimentary feeding among children 6-24 months of age. Specifically the study assessed the porridges' nutritional composition, its contribution to nutrients requirements its sensory properties and consumer acceptability as well as its shelf life stability. Five porridge samples were prepared from a composite flour of soybeans, amaranth grains, pumpkin seeds and orange fleshed sweet potato (SAPO 1-5) and compared to two references (commercial samples) from a composite flour of soybeans, orange fleshed sweet potato and sorghum (SOS) and soybeans, maize, groundnuts, and millet (SMGM). The samples were analyzed and compared for proximate composition, minerals, and vitamin A and C. The nutrient densities in 100ml of the targeted nutrients of interest in this study; energy, protein, vitamin A, iron and zinc were assessed. In 100 ml, SAPO1 had highest energy 117.61 Kcal and protein 3.19g, SAPO2 had highest zinc of 14.47 mg/100 g SAPO4 had highest Vitamin A of 56.11 µg/100 mg while SAPO5 had the highest 20.81mg iron. Zinc and iron extractability was higher in SAPO2 and

SAPO4. In *vitro* protein digestibility ranged (90-99%) in all samples. Sensory evaluation revealed that all porridge samples were accepted by panelists' although SAPO5 was the most accepted by both groups. Attributes like color hue, aroma, sweetness and oiliness were the drivers to consumer liking of the formulated porridge. All attributes tested; appearance, taste, texture and acceptability remained within acceptable limits during four weeks of storage at $45^0$C. Attribute aroma especially for SAPO3 decreased slightly after storage period. SAPO1 predicted to have shortest shelf life of 23 days while SAPO5 had a longest shelf life of 85 days based on Arrhenius equations. Therefore, the utilization of soybeans, amaranth grains, pumpkin seeds and orange fleshed sweet potato can provide products with high nutritional values, high bio-available protein, acceptable attributes and which can stay for a long time. It is therefore recommended from this study that, the awareness on the nutritional benefits, higher bio- available protein and shelf life stability of these foods in complementary feeding should be created to all communities so as to increase their utilization which will also increase its production. This will help in reducing childhood malnutrition in Tanzania which is contributed by the use of low nutrient dense complementary foods.

**Key words:** *complementary food, nutrient dense, soy beans, amaranth grains, pumpkin seeds, orange fleshed sweet potato*

# CHAPTER ONE

## 1.0. INTRODUCTION

### 1.1. Background

Globally, nearly half of all deaths in children under 5 are attributable to under nutrition. This translates into the unnecessary loss of about 3 million young lives a year (Global Nutrition Report 2016). Under nutrition puts children at greater risk of dying from common infections, increases the frequency and severity of such infections, and contributes to delayed recovery. Out of 667 million children under 5years of age worldwide, 159 million are too short for their age (stunted), 50 million do not weigh enough for their height (wasted) and 41 million are overweight (WHO, 2016). The African region is still with the highest prevalence of childhood under nutrition whereby 39.4% of children under 5 years of age are stunted, 10.3% are wasted and 24.9% are underweight (Blessing *et al.,* 2016).

Malnutrition and diet are now the largest risk factors responsible for the global burden of diseases (Forouzanfar *et al.,* 2015). Poor nutrition in the first 1,000 days of a child's life can also lead to stunted growth, which is irreversible and associated with morbidity and mortality, impaired cognitive ability and reduced school and work performance UNICEF (2017); Black et al. (2013) UNICEF, (2011); Mwanri, (2013) and Caufield *et al.,* (2004). Under nutrition doesn't affect only the health and well-being of children but also prevents children from reaching their full potential as well as undermines the strength of their societies. As the 2016 Global Nutrition Report shows, the world has made significant progress towards decreasing stunting, which blights the lives of more than 150 million children around the world.

Tanzania is also faced with childhood under nutrition as it ranks as10$^{th}$worldwide in its contribution to the World's chronically undernourished children (UNICEF, 2009). In Africa, Tanzania ranks as the 3$^{rd}$ worst affected country after Ethiopia and the Democratic Republic of Congo (DRC) (Muhimbula and Zacharia, 2010). According to the Tanzania Demographic Health and Survey(TDHS) (2015-16), 34.4% of children below five years old are stunted (low height-for-age), 4.5% are wasted (low weight-for height), 13.7% are underweight, 69% have anemia, 35% suffer from vitamin A deficiency and 33% are iron deficient. These are high percentages necessitating urgent and effective strategies in addressing this scourge for socio economic development of Tanzania. The review by Muhimbula and

Zacharia, (2010) shows that the main causes of childhood malnutrition are: poor breast feeding practices, timing of introducing complementary food, low –nutrients dense complementary foods as well as high level of microbial contamination in complementary foods. Malnutrition starts in many infants during the complementary feeding period, contributing significantly to the high prevalence of malnutrition in children less than 5 years of age worldwide. Poor feeding practices as well as lack of suitable complementary foods are responsible for under nutrition with poverty worsening the whole issue (Muhimbula, *et al.*, 2011). According to the World Health Organization's (WHO) recommendations, the transition from exclusive breastfeeding and/or infant formula feeding to complementary food, referred to as complementary feeding, typically covers the period from 6 to 24 months of age, and is a very vulnerable period. This is because, after 6 months of age, the contribution from human milk becomes progressively insufficient as a unique nutrient source in relation to the optimal requirements for growth and thus, a greater demand is placed on the complementary food part of the diet (Victor *et al.*,2013).

Tanzania has been at the front position internationally in promoting a conceptual framework for nutrition through its national institution, the Tanzania Food and Nutrition Centre (TFNC).Good nutrition is both a desired outcome for ensuring optimal human health, as well as a key determinant of development, for the individual and for society in general (Leach and Kilama, 2009). Several studies have shown that majority of children in Tanzania are born with the recommended weight of 2.5 kg and start their life in sound health (Mosha *et al.*, 1998). Their growth however, starts to decline during and/or after introduction of complementary foods. Protein, energy and micronutrient deficiencies mostly iron and zinc also become a serious problem as most of these complementary foods consumed do not supply adequate amounts of these nutrients. The Tanzanians widely used weaning foods are based on cereal and non-cereal foods like maize, sorghum, millet, rice, cassava, potatoes, yams and plantains (Kavishe, 2003). Fortified nutritious commercial complementary foods are unavailable especially in the rural areas and where available, they are often too expensive and beyond the reach of most of families in Tanzania (Muhimbula *et al.*, 2011). Therefore consumption of micronutrient dense foods such as animal products is low and subsequently micronutrient deficiencies are widespread (UNICEF 2009). Studies done by Muhimbula and Zacharia (2010) and Mamiro *et al*. (2005) show that Tanzania is dependent on cereal and non-cereal based traditional weaning foods from maize, sorghum, millet, rice, cassava, potatoes, yams and plantains. There is a high rate of childhood under nutrition associated with the use of these starch staples in weaning foods as reported by Mosha *et al.* (2000). In addition such foods are bulky and high in phytate, which limits the bioavailability of nutrients such as iron, calcium, zinc, and in some cases proteins, and energy which are crucial to the development of infants (Gibson *et al.*, 2010).

This study aimed at utilizing locally available nutrient- dense foods like orange fleshed sweet potatoes, soy beans, pumpkin seeds and grain amaranths to produce acceptable and nutrient dense porridge that can be used as complementary food in Tanzania. These ingredients were mainly selected due to their availability and nutrient content.

Tanzania is the second largest producer of sweet potato (*Ipomoea batatas Lam.)* in East Africa with an annual production of more than 333,660 tons per year (FAOSTAT, 2010). Sweet potato currently ranks as the worlds' seventh most important food crop and the fifth most important food crop on fresh weight basis in developing countries, after rice, wheat, maize and sorghum (FAO, 2004). The Tanzania Home Economics Association (TAHEA) has been promoting Orange Fleshed Sweet Potato (OFSP) production for income generation and household food security since the year 2001as a response to the international project "Vitamin A for Africa" (VITAA) (Waized, *et al.,* 2015). Despite this effort, the use of OFSP in complementary foods is not well recognized in Tanzania due to little investment in raising awareness of its nutritional benefits to mothers and caregivers (RAC, 2012). The inclusion of OFSP in complementary foods is important since it provides vitamin A in form of beta carotene, antioxidants, vitamin C, vitamin B6 and minerals (George Foundation, 2015). The sweetness of sweet potato also contributes in improving the flavor of the porridge without the need for using sugar.

Soy beans can potentially contribute to the addition of energy, protein, lipids, carbohydrates, minerals and vitamins (Burks, *et al.*, 1991). Although it is being used as a complementary food in Tanzania, one of the challenges of using soy bean is the presence of phytates and trypsin inhibitors which need to be removed so as to improve its nutritional contribution to the diet. This anti- nutritional content inhibits the bioavailability of nutrients including iron, zinc, calcium and some cases protein which are crucial for the development of infants (Gibson *et al.*. 2010).

Pumpkins are used as food and their seeds are mainly consumed as snacks. Pumpkin seeds are a very good source of minerals such as zinc, iron copper, phosphorus, magnesium and manganese (Revathy and Sabitha, 2013). In addition, pumpkin seeds are also good source of protein and vitamin K (Pongjanta *et al.*, 2006). The inclusion of pumpkin seeds in complementary foods is not well known in Tanzania due to little knowledge about its nutritional benefits. The inclusion of pumpkin seeds in the complementary food will help increase the content of minerals especially iron and zinc which are mostly provided in small amounts in complementary foods used in Tanzania.

Amaranth grain was selected because it contains protein of high quality, calcium, zinc, iron, vitamin A and E, folic acid (Muyonga *et al.*, 2014) which are essential for rapid growth of children. Grain amaranth grown in Tanzania has been used mainly as vegetable (the leaves) but the nutritional benefits of their grains especially in complementary foods has not been evaluated or tapped.

Therefore, the use of these nutrient dense foods mutually with improvement of processing methods will raise their production and consumption and hence improve the health status of children as well as generating income to small holder farmers

**1.2 Problem statement**

Poor quality complementary foods with low nutrient density and poor complementary feeding practices have been identified as the major causes of malnutrition in young children (Victor *et al*., 2008). Notwithstanding numerous nutritional interventions that have taken place in Tanzania, the country still experiences a high rate of childhood under nutrition (UNICEF, 2011). Millions of children suffer from one or more forms of malnutrition resulting in stunting, underweight, wasting and anemia (UNICEF 2009). The Tanzania Demographic Health and Survey (TDHS) (2015), shows 34% of children below five years old are stunted (low height-for-age), 5% are wasted (low weight-for height),69% have anemia, 33% suffer from vitamin A deficiency and 33% are iron deficient. These are high percentages necessitating urgent and effective strategies in addressing this scourge for socio economic development of Tanzania. The use of nutritionally inadequate complementary foods could be one of the factors contributing to malnutrition in Tanzania. The Tanzanians widely used weaning foods are based on cereal and non-cereal foods like maize, sorghum, millet, rice, cassava, potatoes, yams and plantains (Muhimbula and Zacharia, 2010; Mamiro *et al* 2005; and Mosha *et al* 2000). One of the drawbacks of using cereals and tubers for infant feeding is their high bulk, fiber and inhibitors which contribute towards reducing the potential nutritional benefits to children. This bulkiness is associated with starch gelatinization which requires addition of large amounts of water during cooking thus reducing the energy density of these foods (Hurrell, 2003; Mbithi *et al*., 2002). The consumption of low nutrient dense foods contributes to decline in the growth of children around the age of 6 – 24 months and has greater implications for health during adulthood (Muhimbula, and Zacharia, 2010).

The threats of childhood malnutrition to the economic growth of Tanzania are considerable. UNICEF (2010) reported that, vitamin and mineral deficiencies alone cost Tanzania TZS 650 billion (about USD 390 million) in lost revenue each year, which is equivalent to 2.65 percent of GDP. Many studies have been carried out on complementary foods but locally available nutrient dense foods were not involved. There is therefore a need to develop affordable and acceptable nutrient dense complementary porridge flour through utilizing the locally available raw materials. These foods can be easily acceptable and utilized for infant feeding. Orange fleshed sweet potatoes, grain amaranth; pumpkin seeds and soy bean were selected as the ingredients of the porridge flour to be developed. Some of the key issues addressed in this study were the formulation of the ingredients that would provide the required nutrient needs, assessment of its nutrition composition, determination of the contribution of the porridge made from the formulation to the nutrient requirements of children aged 6-24 months and to assess the sensory properties of the porridge as well as the consumer acceptability of the porridge made from the formulated flour.

## 1.3 Research objectives

The overall objective of this study was to develop a nutrient dense complementary porridge from locally available foods for children aged 6-24 months.

## 1.4 Specific objectives

The specific objectives of this study were;

i. To develop a nutrient dense complementary porridge for children aged 6-24 months
ii. To determine the nutrient composition of the orange fleshed sweet potato- based complementary porridge and its contribution to the nutrient requirements of children 6-24 months

iii. To assess the sensory properties and consumer acceptability of the formulated porridge and shelf life stability of the flour.

## 1.5 Significance of the study

As one of the strategies for addressing childhood under nutrition which is contributed by the use of nutritionally poor quality cereal based complementary foods in Tanzania, the information obtained from this study will serve as basis for increasing the utilization of amaranth grains, pumpkin seeds and orange fleshed sweet potato in complementary feeding. Through increased utilization in turn will lead to increased production of these foods and hence increase income for farmers, traders and processors. All these will lead to reduced childhood under nutrition, poverty and food insecurity within families in our communities and in the country.

## 1.6 Hypotheses

1. Composite flour made from Orange Fleshed Sweet Potato, Soy bean, pumpkin seeds, and amaranth grains has more nutrients suitable for growth of children (6-24) months than commonly used composite flour in Tanzania.

2. The use of OFSP, pumpkin seeds, amaranth grains and soybean in complementary foods can contribute in meeting at least 50% of nutrients required by children of (6-24) months.

3. Porridge made from formulated flour will be more acceptable than that made from the commonly used composite flour

# CHAPTER TWO

## 2.0 LITERATURE REVIEW

### 2.1 Childhood malnutrition

Childhood malnutrition accounts for almost one-fifth of global disease burden among children under five years old (Ezzati *et al.*, 2002). It is one of the major and serious public health challenges in developing countries and it accounts for over 50% of childhood mortality worldwide with the most affected group being the children below five years of age (UNICEF, 2011). Globally around 165 million children under the age of five suffer from stunting, 101 million are underweight and 52 million children are wasted and approximately 90 % of these live in just 36 countries with the highest prevalence in Southeast Asia and sub-Saharan Africa (UNICEF, 2013). Risk factors for under nutrition range from distal broad national scale determinants to proximal individual specific and factors which effect at various ages and periods of life (UNICEF, 2013).

Africa is going through a rapid socio-demographic transition, with an alarming increase in childhood under nutrition. Notwithstanding the millennium development goals which targeted reducing hunger by half by 2015, major failures have been recorded mainly in Africa whereby a large number of children is undernourished (Bain *et al.*, 2013). This situation is getting worse in Africa as it is estimated that nearly 30% of infants and children under 5 years old are suffering from one or more of the multiple forms of malnutrition, and about half of 10 million deaths among children under 5 years old in the developing world are associated with malnutrition (UNICEF, 2013 and UNICEF, 2009).

Tanzania is also faced with childhood under nutrition as it ranks as the 3$^{rd}$ worst affected Country in Africa after Ethiopia and the Democratic Republic of Congo (DRC) (Muhimbula and Zachariah, 2010). Worldwide, it ranks as the 10th in its contribution to the World's chronically undernourished children (UNICEF 2009). The Tanzania Demographic Health and Survey (TDHS) (2010), shows that, 42% of children below five years old are stunted (low height-for-age), 5% are wasted (low weight-for height), 69% have anemia, 35% suffer from vitamin A deficiency and 33% are iron deficient. The curent report by Tanzania Food and Nutrition Centre (2014) shows that, the stunting among children under 5 years of age has decreased to 34% and under weight is at 13.4%. These are still high percentages necessitating urgent and effective strategies in addressing this scourge for socio economic development of Tanzania.

### 2.1.2 Causes of childhood malnutrition

Causes of childhood growth faltering are associated by many factors, while the window of period during pregnancy and the first 2 years of life (1000 days) hold a supreme importance (UNICEF, 2013). According to Muhimbula and Zacharia (2010), the main causes of childhood malnutrition in developing countries are poor breast feeding practices, timing of introducing complementary food, low–nutrients dense complementary foods as well as high level of microbial contamination.

### 2.1.3 Effects of childhood malnutrition

Childhood under nutrition during the first two years of life has been associated with irreversible harm and is linked to higher rates of morbidity and mortality, impaired cognitive ability and poor school performance in children (Mwanri, 2013). It also has severe short- and long-term health consequences. Evidence demonstrates that stunting in early life is associated with adverse functional consequences including poor cognition and educational performance, low adult wages, lost productivity and, when accompanied by excessive weight gain later in childhood, increased risk of nutrition-related chronic diseases (Victora *et al*.,2008). Furthermore, another study done by Caulfield *et al*. (2004) shows that, half of all child deaths are attributable to malnutrition.

### 2.1.4 Interventions to reduce childhood malnutrition

Many programs have been conducted worldwide to reduce childhood malnutrition particularly during the critical period from conception to 24 months of age. The first target addresses the scourge of stunting and aims to reduce by 40% the number of stunted children under 5 years of age in 2025 (WHO, 2012). Other interventions that have been carried out to reduce childhood malnutrition include the early start and prolonged duration of breast-feeding, timely introduction of proper and improved complementary feeding practices, and regular growth monitoring. Many nutrition programs with focus on complementary feeding and micronutrient deficiencies have been implemented in different countries including Tanzania to prevent and address micronutrient deficiencies through supplementation or fortification (Mwanri, 2013). Despite all these interventions, there is still a problem in complementary feeding in Tanzania whereby most of homemade complementary foods are less nutrient dense because of traditional culture of feeding children with only commonly used foods which do not fulfill the nutrients requirement of children (Mamiro *et al.,* 2005 and Mosha *et al.,* 2000).There are existing interventions which if implemented can reduce this burden significantly. But there is a need for greater priority for national nutrition programs, stronger integration, enhanced inter-sectoral coordination, and more focus and coordination in the global nutrition system of international agencies, donors, academia, civil society, and the private sector in achieving better nutrition for children under 5 years of age (WHO, 2012).

### 2.2 Complementary foods

According to World Health Organization's (WHO) recommendations, the transition from exclusive breastfeeding and/or infant formula feeding to complementary food, referred to as complementary feeding, typically covers the period from 6 to 24 months of age, and is a very vulnerable period. This is because, after 6 months of age, the contribution from human milk becomes progressively insufficient as a unique nutrient source in relation to the optimal requirements for growth and thus, a greater demand is placed on the complementary food part of the diet (WHO, 2010). It is the time when malnutrition starts in many infants, contributing significantly to the high prevalence of malnutrition in children less than five years of age worldwide and affecting subsequent optimal development (Victor *et al.*, 2013 and Mosha *et al.*, 2000). In developing countries like Tanzania, malnutrition diring complementary feeding are mainly attributed by low- nutrient dense foods which are given to children as weaning foods.

#### 2.2.1Complementary foods in Tanzania

Studies done by Mamiro *et al*., (2005), and Muhimbula, (2010) show that Tanzania is dependent on cereal and non -cereal based traditional weaning foods from maize, sorghum, millet, rice, cassava, potatoes, yams and plantains. It also depends on starchy roots with high fiber content and pulses in both rural and urban areas. These starchy foods provide almost three quarters of the total energy supply, despite the wide variety of food produced in Tanzania (Leach and Kilama, 2009). There is a higher rate of childhood under nutrition associated with the use of these starch staples in weaning foods (Mosha *et al.,* 2000). In addition such foods are bulky and high in phytate, which limits the bioavailability of nutrients, including iron, calcium, zinc, and in some cases proteins, and energy which are crucial to the development of infants (Gibson *et al*, 2010). Even though commercial foods which are of high nutritional quality are available in the market, they are often expensive and thus unaffordable by low income people (Muhimbula *et al*,. 2011). Consumption of micronutrient dense foods such as animal products are low due to unaffordability and subsequently micronutrient deficiencies are wide spread (UNICEF, 2009). There are plenty of nutrient dense plant foods in Tanzania which can be incorporated in complementary feeding so as to provide children with required amount of nutrients needed for their growth. Despite this opportunity most of Tanzanians are not aware of the nutritional benefits of these foods in complementary feeding. This therefore necessitates an urgent need of creating this awareness to people in Tanzania through utilizing different nutrient dense plant foods in complementary feeding.

### 2.2.2 Guidelines for complementary feeding

According to WHO, (2010) and FAO, (2011), complementary feeding should be started when the baby can no longer get enough energy and nutrients from breast milk alone. For most children this is between 4 and 6 months of age. This is the suitable age because, during this age the baby`s muscles in the mouth have developed sufficiently to let the baby munch, bite and chew which makes it easier to feed thick porridges, puree and mashed foods.

Giving complementary foods too soon is associated with some dangers. Among the dangers for early complementary feeding are; the food may displace breast milk, the child may take less milk, the mother produces less milk and hence in later time it may be more difficult to meet child`s nutritional needs (FAO, 2011). Other dangers are low proactive factors from breast milk, increased risk of diarrhea because complementary food may not be as clean as breast milk (Safari *et al.,* 2013). Moreover, these foods fill the stomach but provide fewer nutrients than the breast milk, and so the child`s needs are not met. Starting complementary feeding too late is also dangerous. This is because a child does not get the extra food needed to fill the energy and nutrient gaps, a child may stop growing or grows slowly as well as the increased rate of malnutrition and micronutrient deficiencies (Brown and Dewey, 2003; Dewey, 2001).

### 2.2.3 Portion size and feeding frequency

In early infancy (0 to < 6 months), exclusive breastfeeding with adequate frequency of feeding times is the optimal feeding pattern (Brown and Dewey, 2003). From 6 to 8 months, children are in transition to complementary feeding, as they are given solid foods to supplement breastmilk intake. Although the concentration of a number of nutrients naturally decreases during this period, breast milk from a well-nourished mother remains the primary source of protein (up to 80 percent), vitamin A, folate, and vitamin C (UNICEF, 2011). The main problem at this stage is inadequate energy and nutrient density of complementary foods. Complementary foods during this stage are vital for provision of the primary source of calcium, iron, and zinc; they also contribute to thiamin, riboflavin, and niacin intake (Lwelamira *et al.,* 2013). Nutrient intake, food volume and feeding frequencies increase as children grow older. Studies done by Lutter (2013); and Dewey, (2001) show that children of 9 to 11 months need increasing amounts and varieties of solid foods in addition to breast milk. Since children's stomach capacity is still small, 3 to 4 feeds of 720mls a day is needed to accommodate their increasing energy needs. For children in their second year of life (12 to 23 months), increased total food intake, frequent feeds of 900mls a day of varied nutrient-dense foods is needed.

## 2.3 Selection of raw materials for infant porridge formulation

Weaning of a child is a gradual process by which an infant is introduced to adult diet. Weaning food is a special formulation, which is a supplement to the breast milk. several strategies have been used to formulate baby food (Parvin *et al.*, 2014 and Lalude and Fashakin, 2006)through a combination of locally available foods that complement each other in such a way that provide the recommended daily allowance for infants. According to the (FAO/WHO, 1989), an ideal formulated baby food must be nutrient dense, easily digestible, of suitable consistency and affordable to the target market. Therefore, development of complementary foods based on locally available foods has been suggested by the Integrated Child Development Scheme (ICDS) and Food and Agriculture Organization (FAO) to combat malnutrition among mothers and children of low socio-economic groups.

Despite all these efforts, it is evident that the commercial formulated complementary foods currently available are not affordable to many low income families (Parvin *et al.*, 2014 and Muhimbula *et al.,* 2011). Even though there are homemade complementary foods in Tanzania, studies by Muhimbula and Zachariah, (2010) and Mamiro *et al*. (2005) show that most of these foods are based on only commonly used foods such as maize, plantains, millet, sorghum, rice, cassava and potatoes. These foods produce bulky complementary foods that need too much dilution and hence reduce the nutrient content of the porridge. This study aimed at utilizing locally available nutrient- dense foods like orange fleshed sweet potatoes, soy beans, pumpkin seeds and grain amaranths to produce acceptable and nutrient dense porridge that can be used as complementary food in Tanzania. These ingredients were mainly selected due to their availability and nutrient content

### 2.3.1 Pumpkin seeds

Pumpkin fruit (*Cucurbita pepo*) is a squash-like gourd in the *Cucurbitaceae* family of vegetables native to Mexico (Atuonwu and Akobundu, 2010). Pumpkin seeds (*pepita*) are edible kernels of fruit pumpkin. Pumpkin seeds are flat, dark green seeds, with some encased in a yellow-white husk. They have a malleable, chewy texture, and have a subtly sweet, pleasantly nutty flavor (Campbell and Gold, 2009).The seeds, in-fact, are concentrated sources of many health-benefiting vitamins, minerals, anti-oxidants, as well as important essential amino-acids such as tryptophan, and glutamate. Pumpkin seed are rich in zinc, iron and copper, phosphorus, magnesium and manganese (Cascio, 2010). Pumpkin seeds are also good sources of protein and vitamin K (Hamed *et al*., 2008).

Furthermore, another study by Revathy, and Sabitha (2013) found that the pumpkin seeds also contain beta carotene and thus the beta carotene present in pumpkin seeds and flesh has antioxidant and anti-inflammatory properties. They are also a rich source of essential fatty acids, which have numerous health benefits like providing protection against serious health diseases such as high blood pressure, arthritis, cancer, promoting healthy skin and improving brain power (Pongjanta *et al.*, 2006). The unique nutritional and health benefits of pumpkin seeds has contributed to increasing their popularity in recent years. Since all minerals and other nutrients present in pumpkin seeds are essential for growth and development of children, inclusion of pumpkin seeds in complementary foods will help children to get those benefits which will facilitate proper growth and development.

**Figure 1: Pumpkin seeds**

### 2.3.2 Soy beans

Soybean (*Glycine max*) is one of the most important food plants of the world, and seems to be growing in importance. It is an annual crop, fairly easy to grow, that produces more protein and oil per unit of land than almost any other crop. It is a versatile food plant that, used in its various forms, is capable of supplying most nutrients. Soybean is popular in infant foods because it is largely produced in the world, low cost and desirable nutritional and functional properties that make it  a substantial contribution to the world`s food protein requirement (Tanzania Food and Nutrition Centre, TFNC, 2003). It can substitute for meat and to some extent for milk (Artin, 1998). It is a crop capable of reducing protein malnutrition (Ishaq and Ehirim, 2014).  Soy bean is an abundant and economical source of protein which is apparently cheaper than animal source protein and contains all essential amino acids (Laswai and Kulwa, 2010).Large world production, low cost and desirable nutritional and functional properties of soybean make it a substantial contribution to the world's food protein requirements. Soy protein is normally used as a supplement in different forms of food for the purpose of improving protein quality (Malema *et al.*, 2005). Additionally, soybean can be used for many purposes like for soymilk, soy sauce, tofu (soybean curd), yoghurt, flour for porridge and in some beverages. Since soybean is also a good source of some micronutrients, it can be used to reduce the prevalence of malnutrition in Tanzania (Kavishe, 2003).

Despite its nutritional benefits,  soybean requires careful home processing to bring out its best qualities, and if not well prepared, it has an off-flavor  and anti- nutritional factors that are infrequently appreciated (Artin, 1998).  Soybeans can be processed through roasting, fermentation and germination. Ramaman, *et al.* (1996) emphasized the importance of processing soybeans as they contain undesirable flavor, bitterness, toxic proteins, haemagglutinins and anti-trypsin. These substances must be destroyed or deactivated to make the beans palatable and digestible both for human and animal consumption. The soybean acceptance can be improved through modification of processing methods like; application of heat, soaking of soybean in ethanol or alkali and blanching the beans in hot water. The present study is utilizing soy beans for the addition of the energy, protein, lipids, carbohydrates, minerals and vitamins (Burks *et al.*, 1991).

**Figure 2: Soybeans**

### 2.3.3. Orange Fleshed Sweet Potato (OFSP)

Orange-fleshed sweet potato (OFSP) refers to varieties of sweet potato (*Ipomoea batatas*) that are rich in beta-carotene, a vitamin A precursor. OFSP is extremely rich in bioavailable beta-carotene, which the body converts into vitamin A (retinol) at a ratio of 12 to 1(Reaching Agent for Change (RAC), 2012).This beta-carotene content gives the tubers their orange color. According to Waized *et al.* (2015), about 125g of most OFSP varieties can supply the recommended daily allowance of vitamin A for children of 300µg and 700µg non-lactating mothers.On top of beta carotene, OFSP also contains other vitamins like C, E, K and B(International Potato Centre (IPC), 2010). The study added that OFSP contains antioxidants and some minerals and their leaves also have good micronutrient contents and adequate protein (4%) for use as food and animal feed. In Tanzania, the vast majority of sweet potato production is of white-fleshed varieties (WFSP). WFSP, although a good source of calories, is not a good source of vitamin A or other micronutrients (Somuah *et al*, 2013). Improved OFSP varieties first arrived in Tanzania in the Lake zone apparently brought from neighboring regions in Rwanda and Uganda where agricultural initiatives had introduced them. Common varieties include *Simama, Mataya, Kiegea, Kabode, Jewel, Carrot Dar* and *Carrot C*(Waized *et al*., 2015). The crop is grown almost in all agro-ecological zones (Lake Zone, Western Zone, Southern Highlands Zone, Eastern Zone and Northern Zone) because of its hardy nature and broad adaptability, hence providing a sustainable food supply when other crops fail (Ndunguru and Rajabu, 2000 Kapinga *et al.,* 1995; and Jana, 1982). After its introduction in the Lake Zone, OFSP gradually spread to other regions of the country. Nonetheless, uptake has been limited, with only a small number of farmers cultivating OFSP due to unfamiliarity to the people as well as unawareness of its nutritional benefits. Unlike WFSP, OFSP tubers are available in markets only in the areas of production and only during the production seasons (Sindi and Wambugu, 2012). Its popularity can be improved through; nutrition education, distribution of subsidized vines, marketing campaign for orange brand as well as other activities that encourage diffusion of OFSP

**Figure 3: Orange fleshed sweet potato**

The Tanzanian National Sweet potato Research Program has already incorporated Orange Fleshed Sweet Potato (OFSP) into its conventional breeding efforts because it values bio fortified crops and staple foods with very high levels of at least one essential micronutrient. OFSP has the potential for reducing vitamin A deficiencies in Tanzania, particularly in young children. It is estimated to be the most affordable source of this micronutrient, and can be incorporated into a number of popular foods like complementary foods, snacks and as a staple food (Helen Keller International (HKI), 2012). In most parts of Tanzania, sweet potato has gained importance due to its adaptability to marginal conditions such as drought, wet conditions, low soil fertility, and is ranked high as food security crop when local staple crops like maize and rice are scarce or fail (RAC, 2012). Therefore its inclusion in complementary feeding will facilitate its production and utilization in different places in the country.

### 2.3.4 Amaranth grains

Amaranth (*Amaranthusspp*) is an herbaceous annual plant with upright growth habit, cultivated for both its seeds, which are used as a grain, and its leaves which are used as vegetables. Both leaves and seeds contain protein of unusually high quality due to its high portion of lysine, an essential amino acid (Muyonga *et al.*, 2014). Amaranth is often called a pseudo cereal because it is used much like cereal grains although it is not in the grass family. Grain amaranth belongs to the cosmopolitan *Amaranthus* genus of some 60 species (National Research Council (NRC), 1984).Compared to common starchy staples, grain amaranth also contains higher levels calcium, zinc, iron as well as vitamins A, E and folic acid (Muyonga *et al.*, 2014).The leaves are a good source of vitamin A, C, K and folate. Amaranth  may also provide unique health benefits with some studies showing that regular consumption may reduce blood pressure and cholesterol levels, while improving antioxidant status and some immune parameters (Chauhan and Singh, 2013).

It is well known that grain amaranths and many other amaranth species show incredible potential for human consumption and other uses, and are particularly promising as a remedy for hunger and malnutrition in developing countries (Teutonico, 1985).Grain amaranth can also be used in numerous recipes, ranging from popped amaranth snack, porridge, chapattis creamy soup, snacks, and pancakes. Grain amaranth has a relatively high proportion of lysine, an essential amino acid, compared to other foods. A crop indigenous to Africa, amaranth is highly versatile and grows easily and prolifically in the humid tropics, survives in high altitudes and it is known as "drought crop" that thrives in hot and dry weather (Tenywa, 2012). The physicochemical properties and nutritional composition of grain amaranth make it a good choice to blend it with other flours, for preparation of nutrient dense porridge which can be used to improve nutrition status of vulnerable groups like pregnant women and infants (Emire and Arega, 2012). Studies by Okoth *et al.* (2016); Oladimeji (2015) and Muyonga *et al.* (2014) have shown how amaranth grains were incorporated in different foods whereby it resulted to increased nutrients especially proteins as well as improved sensory attributes with high acceptability.

**Figure 4: Amaranth grains**

**Table 1: Composition of the targeted nutrients in the selected foods**

| Nutrients | Amaranth grains | Soybeans | OFSP | Pumpkin seeds |
|---|---|---|---|---|
| Energy (Kcal) | 371.00 | 446.00 | 86.00 | 747.00 |
| Protein (g) | 13.56 | 36.49 | 1.57 | 118.00 |
| Vitamin A (**µg**) | 0.00 | 13.00 | 709.00 | 524.00 |
| Iron (mg) | 7.61 | 15.70 | 0.61 | 20.70 |
| Zinc (mg) | 2.87 | 4.90 | 0.30 | 10.30 |

**Source: USDA, (2016).**

### 2.4 Infant feeding

For most children, introduction of other foods apart from breast milk starts at the age of 4 - 6 months. When introducing solid foods to infants, it is recommended to start with small amounts of food and increase the quantity as the child gets older, while maintaining frequent breastfeeding (Brown and Dewey, 2003 and Dewey, 2001). The energy needs from complementary foods for infants with average breast milk intake are approximately 550 kcal/and 580kcal per day at 12-23 months of age for developing and industrialized countries respectively (UNICEF, 2013).

In practice, caregivers will not know the precise amount of breast milk consumed, nor will they be measuring the energy content of complementary foods to be offered. Thus, the amount of food to be offered should be based on different combinations, taste and texture while assuring that energy density and meal frequency are adequate to meet the child's needs (Kathyrn, 2001). Food consistency and variety should be increased gradually as the infant gets older, adapting to the infant's requirements and abilities. Infants can eat pureed, mashed and semi-solid foods beginning at six months. By 8 months most infants can also eat finger foods (snacks that can be eaten by children alone). By 12 months, most children can eat the same types of foods as consumed by the rest of the family. Avoid foods that may cause choking or consistency that may cause them to become lodged in the trachea, such as nuts, grapes, raw carrots (UNICEF, 2013).

### 2.4.1 Guidelines for infant feeding

As guidelines for infant feeding, start at six months of age by giving small amount of food and increase the quantity as the child gets older, while maintaining frequent breast feeding (Ministry of health and social welfare, 2013). When giving complementary foods, ensure that the energy needs from complementary foods for infants are met. Infant feeding should be practiced by applying principles of psycho-social care These principles hold different practices like; feed infants directly and assisting older children when they feed themselves, being sensitive to their hunger and satiety cues, feeding slowly and patiently, encouraging children to eat but do not force them if children refuse many foods, trying out different food combinations, tastes, textures and methods of encouragement, minimizing distractions during meals if the child loses interest easily and  remembering that feeding times are periods of learning and love (Pelto *et al.,* 2002 and Engle *et al.,* 2000). Also, talking to children during feeding with eye to eye contact is advised. All these practices facilitate a friendly environment and encourage children to eat (Dewey, 2001).

There is increasing recognition that optimal complementary feeding depends not only on what is fed, but also on how, when, where, and by whom the child is fed (Pelto *et al.,* 2002). Behavioral studies done by Bentley *et al*. (1991) and Engle (2000) reveal that, a tolerant style of feeding dominates in some populations with encouragement to eat is not always practiced unless when children refuse to eat or when they are sick. However, the evidence to date on the impact of feeding behaviors on dietary intake and child health is sparse. Another study done by Ruel *et al.* (2009) in an urban population in Ghana, found that a care practices scale which included breastfeeding patterns, timing of complementary feeding, food quality, and two active feeding behaviors was positively associated with child anthropometric status among mothers with little or no schooling. Moreover, other intervention studies (Creed de Kanashiro *et al.,* 2002 and Sternin *et al.,* 1997) that included feeding behaviors as part of the recommended practices have reported positive correlation on feeding behaviors and child growth.

### 2.4.2 Nutritional requirements for children aged 6-24 months

Proper nutrition by good feeding of infants and young children are among the most important determinants for their health, growth and development.The nutritional requirements of infants and children differ according to age and gender (Michaelsen *et al*., 2000).Energy and protein are essential for children because they are important macronutrients required for adequate growth and development. Together with these, micronutrients such as iron, vitamin A and zinc are of concern for children (UNICEF, 2009). Foods such as fruits, vegetables, animal products as well as fortified foods which are rich in micronutrients should be adequately given to children so as to prevent micronutrient deficiency (WFP, 2012; WHO 2005; and UNICEF, 2006). The Recommended Daily Intake (RDI) of children aged 6-23 month is shown in Table 2.

**Table 2: Nutrient requirements for children aged 6-24 months**

| Nutrients | Children 6-8 months | Children9-11months | Children12-24 months |
|---|---|---|---|
| Energy | 682 Kcal | 830 Kcal | 1,092Kcal |
| Protein | 9.1 g | 11 g | 13g |
| Vitamin A | 400 µg | 300 µg | 300 µg |
| Iron | 0.27mg | 11 mg | 7mg |
| Zinc | 2 mg | 3 mg | 3mg |

**Sources: WHO, (2005), WHO/UNICEF, (1998).**

### 2.5 Sensory evaluation

Sensory evaluation is a scientific method that suggests, measures, analyses and interprets responses to products as perceived through the sense of sight, smell, touch, taste and sound. In determining how food product affects consumers, senses are one of the most important goals not only for food industry but also for nutritionists and dieticians who develop healthier recipes. For the reason that our senses act as gatekeeper of our bodies, the healthy foods will be picked only if our senses accept it. Therefore, consumer reactions as perceived by our five senses are considered as vital measures of food development. Since no apparatus can substitute for senses in testing foods, humans are used as test subjects. These studies are becoming more prevalent despite the potential biases of humans and the costs involved (Learning and  Choi, 2014).

The environment in which sensory test is conducted should be carefully controlled and samples must be prepared in a uniform fashion so as not to influence panelists` perception of the foods` quality (Lawless and Heyman, 2010). Panelists` who are well suited to the purpose of the sensory test should be selected and trained appropriately.

### 2.5.1 Acceptability and descriptive tests

Types of sensory tests used in evaluating food quality are analytical and effective tests. Analytical tests are based on noticeable differences whereas effective tests are based on individual acceptability or preferences. This shows how consumer perceives food product. The advantage of this type of sensory evaluation is to show whether consumers accepted the products or not, and the consumer ranked the food attributes based on hedonic scale (Lawless and Heyman, 2010). Analytical test is divided into difference test (discriminative test) and descriptive test (Murray *et al.,* 2001).

The descriptive type of sensory evaluation deals with quantifying the intensities of the sensory attributes of the food product. The advantage of this type of sensory evaluation is to show the magnitude of differences and intensities of food attributes (Adins *et al.,* 2014). When conducting this type of sensory evaluation; you should train judges so as to have common understandings in rating food attributes. This will help improves an individual`s sensitivity and memory to provide precise, consistent and standardized sensory measurements (Meenakshi *et al.,* 2010). Depending on the main task of the test effective tests are either acceptance or preference tests. The primary task of acceptance tests is to rate the degree of liking while with preference test the goal is to identify the item that is more liked (Learning and  Choi, 2014).

### 2.5.2 Effect of ingredients on sensory characteristics

The characteristics of foods and their ingredients are perceived differently by our five senses; sight, smell, touch, taste and sound.

### 2.5.3 Sight

The eyes perceive the initial quality of the foods as color shape, size, texture, consistence and opacity. Color may accurately indicate ripeness, strength of dilution and the degree to which the food has been heated, to evaluate desirability and acceptability of the food. Food`s color sends visual signals that triggers certain expectations in mind that can change person`s choice though the food color may be deceiving sometimes. Even small visual details such as adjacent or background color and the relative sizes of area of contrasting color can affect consumer`s perception (Lawless and Heyman, 2010).

### 2.5.4 Smell

Smell or olfactory sense also contributes to our evaluation of food quality. The volatility of odors is related to temperature because only volatile molecules in terms of gas carry odor since it is easier to smell hot foods than cold ones. Human subjects have varying sensitivities to odor depending on hunger, satiety, mood, concentration, presence or absence of respiratory infections and gender. Because different people perceive a given odorant differently, identifying new odor from a food a food product requires as large a person as possible to get valid results.

### 2.5.5 Taste

Taste or the perception of gustatory input is the most influential factor in person`s selection of a particular food. For the product to be tasted, it has to be dissolved in water, oil or saliva. Taste is perceived by taste buds which are primarily on the surface of the tongue by the mucosa of the palate and in areas of the throat. The sense of taste varies by gender and race. Beyond the genetic variation in taste perception also depends on how perceptible sweet, fatty and bitter compounds are in foods and beverages. It also depends on the value a consumer places on other factors such as health and convenience (Duffy and Bartoshuk, 2000).

### 2.5.6 Sound

This is another sense which is used to evaluate food quality such as sizzling, crunching, popping, bubbling, squeaking, dripping, exploding and crackling can communicate much about a food. Most of these sounds are affected by water content thus their characteristics indicates a food`s freshness and ripeness (Brown, 2008). Sound is detected as vibration in the local medium, usually air. The vibrations are transmitted via the small bones in the middle ear to create hydraulic motion in the fluid of the inner ear, the cochlea. For an individual to give the sound/ texture of the food, he/she has to feel it from the mouth.

### 2.5.7 Touch

This is a sense that brings impression of a food texture to us through oral sensation or the skin. Texture is the sensory manifestation of the structure or inner makeup of the products interms of their reactions to stress which are measured as mechanical properties such us hardness, firmness, adhesiveness, cohesiveness, gummines and viscosity by the kinesthetic sense in the muscle of thee hands, fingers tongue, jaw or lips. Texture also includes tactile feel properties which are measure as geometric properties or moisture properties by the tactile nerves in the surface of the skin, hands, lips or tongue. The greater surface sensitivity of the lips, tongue, face, and hands makes easy detection of small differences in particle size, thermo and chemical properties possible among food products (Meilgaard *et al.,* 2007).

## 2.6 Extrusion Cooking Technology

Extrusion cooking is a high-temperature, short-time process in which moistened, expansive, starchy and protenacious raw material is used. Food materials are plasticised and cooked in a minute by a combination of moisture, pressure, temperature and mechanical shear, resulting in molecular transformation and chemical reactions (Moscicki *et al.,* 2011). Extrusion reduces the microbial count and inactivates enzymes (Navale *et al.*, 2015). This process combines several unit operations including mixing, cooking, kneading, shearing, shaping and forming. Extrusion technologies have an important role in the food industry as efficient manufacturing processes. Extrusion cooking has gained in popularity over the last two decades for a number of reasons like versatility, low cost, productivity, provision of ready-to use product, retention of product nutrient quality as well as environmentally-friendly (Sundarrajan, 2014).As a low-moisture process, extrusion cooking does not produce significant process effluents, reducing water treatment costs and levels of environmental pollution (Moscicki *et al.,* 2013). Based on ability of extrusion cooking technology of combining several unit operations like mixing, cooking, kneading, shearing, shaping and forming so it is a highly versatile unit operation that can be applied to a variety of food processes. Extrusion has for years provided the means of producing new and creative foods. One major advantage of extrusion cooking is the capability to produce a wide range of finished products with minimum processing times and by using inexpensive raw material (Riaz, *et al.*, 2007).

Food extruders belong to the family of high temperature short time (HTST) equipment, capable of performing cooking tasks under high temperature, high pressure and for short time (Fellows,2000). This technology serves as an advantage for vulnerable foods and feeds as exposure to high temperature but for only short time will prevent destruction of nutrients. The results of extrusion are gelatinization of starch, denaturation of protein, partial dextrinization of starch, inactivation of many native enzymes, reduction of microbial count and improvement of digestibility of the product. Moreover, extrusion cooking improves the protein value of the product by breaking down the native protein structure including enzyme inhibitors and lectins as well as breaking down phytic acid in the seeds which then leads to increased protein content in the food (Shimelis and Rakshit 2007 and Prakrati *et al.* 1999) as well as reducing the activity of some anti- nutritional factors in the product such as trypsin inhibitors, and undesirable enzymes, such as lipases, lipoxidases and microorganisms (Pathania *et al.*, 2013). Extrusion cooking may even reduce pasting property of flours and hence extruded flours will require minimum temperature to cook (Kaur *et al.*, 2007).

### 2.6.1 Types of extruders

There are two types of extruders used for food production: single-screw extruders and twin screw extruders. Single-screw extruders are the most common extruders used in the food industry. Twin-screw extruders are used for high-moisture extrusion, products that include higher quantities of components such as fibres, fats, etc. and more sophisticated products (Steel *et al.*, 2012).

### 2.6.2 Single-screw extruders

Single screw extruders contain a single rotating screw in a metal barrel, and come in varying patterns. They are the most common extruders applied in the food industry. The classification of single-screw extruders can be defined based on process or equipment parameters such as: conditioning moisture content (dry or wet), solid or segmented screw, desired degree of shear and heat source. However, practically, the main classification used considers the degree of shear and the heat source (Steel *et al.,* 2012). In single –screw extruders the raw materials are fed in a granular form at the hopper located in the feed section. The rotating action of the screw conveys the material to the transition section. In the transition section, the screw channel becomes shallower and the material is compacted. The barrels of single-screw extruders usually have helical or axial grooves on inner surfaces. This helps to convey and mix the material more effectively (Ramachandra and Thejaswini, 2015).

### 2.6.3 Twin screw extruders

These are types of extruders which are composed of two axes that rotate inside a single barrel. Generally the internal surface of the barrel of twin-screw extruders is smooth. Depending on the position of the screws and their direction of rotation, four different types of configurations are possible: co-rotating intermeshing screws; co-rotating non-intermeshing screws; counter-rotating intermeshing screws; and counter-rotating non-intermeshing screws. (Steel *et al.,* 2012).The advantage of using twin screw extruders is versatility to process a wide range of products like tortillas, cereal snacks, extruded corn snacks, and multigrain snacks. However, this type of extruder is little used in the food industry, even though they present more efficient displacement properties (Ramachandra and Thejaswini, 2015).

The principle of the extrusion process involves the loading of raw materials in the feeding hopper from where the screw conveys them through a barrel under pressure. The materials are compressed into a semi-solid, plasticized mass as they pass down the barrel. The selection of right extruder for the production of ready to eat (RTE) or cereal snacks depends on the nature of raw materials used, bulk density and type of product to be produced (Fellows, 2009).The effects of extrusion cooking on nutritional quality are ambiguous. Benefits include destruction of anti-nutritional factors, gelatinization of starch, increased soluble dietary fibre and reduction of lipid oxidation. Starch digestibility is largely dependent on complete gelatinization. High starch digestibility is essential for specialized nutritional foods such as infant and weaning foods. Creation of resistant starch by extrusion may have value in reduced calorie products (Ramachandra and Thejaswini, 2015).

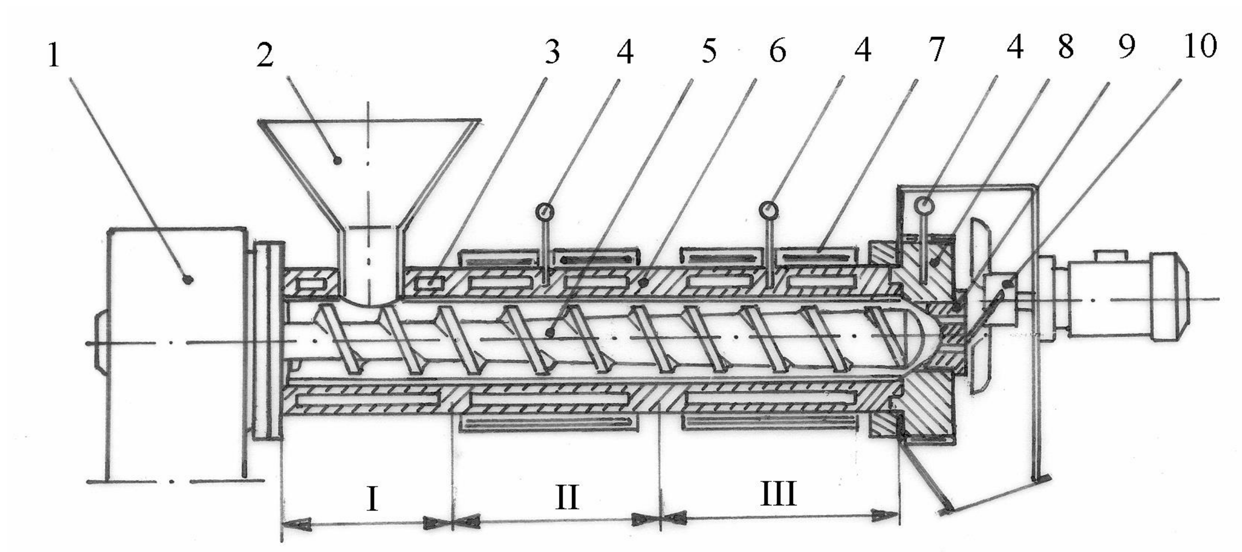



**Figure 5: A cross-section of a single-screw extrusion-cooker: 1 - engine, 2 - feeder, 3 - cooling jacket, 4 - thermocouple, 5 – screw, 6 - barrel, 7 - heating jacket, 8 - head, 9 - net, 10 -cutter, I - transport section, II – compression section, III –melting and plasticization section (Mościcki et al., 2013).**

### 2.7 Shelf life study

Shelf life is a time during which the food product will remain safe, be certain to retain organoleptic qualities, chemical, physical and microbiological characteristics as well as complying with any label declaration of nutritional data when stored under recommended conditions (Kilcast and Persis 2003). The shelf life of different food products start from the day the product is manufactured and its length varies based on ingredients used, manufacturing processes, storage conditions as well as packaging materials (Jaya and Das, 2005).There are many factors which can influence shelf life and can be grouped into intrinsic and extrinsic factors (IFST, 1993). Intrinsic factors include the properties of the final product such as water activity (water available), pH value and total acid, redox potential, available oxygen, nutrients, natural micro flora and surviving microbiological counts, natural biochemistry of the product formulation (enzymes, chemical reactants) as well as use of preservatives in product formulations. Extrinsic factors are those factors the final product meets as it moves through food chain. Those factors include time- temperature profile during processing, temperature control during storage, relative humidity during processing, storage and distribution, exposure to light, composition of atmosphere within packaging, subsequent heat treatment as well as consumer handling(Kilcast and Persis 2003; IFST 1993 and Mcginn, 1982).

There are two ways which can be used to determine shelf life of the product, one being direct method which is mostly used and another is accelerated shelf life study. In determining the shelf life of the product using a direct method requires a considerable amount of experimentations, consequent costs and time. Therefore, in order to shorten this process, accelerated shelf life testing (ASLT) by storing the product in an elevated temperature can be used (Mizrahi, 2000). Accelerated shelf life refers to a method that is capable of evaluating product stability using significantly shorter period than actual shelf life of the product (Kebene *et al.,* 2015 and Kilcast and Persis 2003). This technique shortens the storage time and increases the deterioration of the product through increasing the storage temperature (Yang *et al.,* 2013 and Martin and Silva, 2004). Based on techniques in ASL study, it can significantly help in shortening the shelf life duration to half or quarter of the direct method (Corradini and peleg, 2007).

The results obtained from this technique can be used to estimate the shelf life of a product under normal storage conditions through the use of linear or Arrhenius equations (Gulla and Waghray, 2012). The principle factor which affects the kinetics of reactions in processed and dried food is temperature. The increased temperature is known for accelerating the deteriorative reaction in foods which then reduces their shelf life period (Labuza, 1982). Temperature in accelerated shelf life is assumed to follow the Arrhenius equation.

Arrhenius equation; $K = k_o \exp^{(Ea/RT)}$

Where: K= rate constant $K_o$= Pre exponential constant $E_a$= Activation energy R= Gas constant T= Absolute temperature.

Arrhenius equation serves as the best approach in modeling temperature dependence. Unlike other models of temperature dependence, Arrhenius model has a thermodynamic basis (Labuza and Kamman, 1983 and Saguy and Karel, 1980). The activation energy in this equation is derived from the slope of a plot of natural logarithim of rate of constant (k) versus the inverse of absolute temperature which depends on compositional factors like water activity, moisture content and solid concentration. Predicting shelf life using calculations of the temperature dependence reactions is associated with large statistical errors. Therefore, study by Cohen and Saguy (1985) suggests the use of Arrhenius plots in predicting shelf life based on a known end point quality deterioration value. Labuza and Riboh,(1982) added reported that there could be many other limitations besides statistical errors in using Arrhenius plot to predict shelf life at lower temperature because some reactions which predominate at higher temperature do not pre dominate at lower temperature.

# CHAPTER THREE

## 3.0 RESEARCH MANUSCRIPT

### 3.1 Development and nutritional evaluation of a nutrient dense complementary porridge flour from locally available foods in Tanzania


**Abstract**

Poor growth and development in many infants starts during or after introduction to complementary feeding period, contributing significantly to higher prevalence of malnutrition in children less than 5 years of age. This has been contributed by nutritionally poor quality complementary foods which are mostly cereal based. The cereal based foods are low in nutrient content and also associated with high bulkiness which requires too much dilution which tends to reduce energy content. It is from this point that this study was carried out to utilize the locally available foods; soybeans, amaranth grains, pumpkin seeds and orange fleshed sweet potato to develop a nutrient dense complementary porridge flour and determine its nutritional composition and amount of targeted nutrients in this study which were energy, protein, vitamin A, iron and zinc. Five composites flours (SAPO1-SAPO5) were developed. Two commercial formulations SOS and SMGM were used as control samples. About 350 g of each flour was used to make porridge and assessed for their proximate compositions, vitamin A and C, minerals, in *vitro* protein digestibility and nutrient densities. Nutrient density of the targeted nutrients in 100 ml showed that SAPO1 had highest energy (117.61Kcal) and protein 3.19g/100 g, SAPO2 had highest zinc content of 14.47mg/100 g; SAPO4 had highest Vitamin A content of 56.11µg/100g while SAPO5 had the highest iron content of 20.81mg/100 g. Zinc and iron extractability was higher in SAPO2 and SAPO4. In *vitro* protein digestibility of all formulations was high (90-99%). Based on the targeted nutrients in this study, it can be concluded that, utilization of soybeans, amaranth grains, pumpkin seeds and orange fleshed sweet potato can help in improving energy, protein, vitamin A, iron and zinc contents of complementary porridges used in Tanzania. Therefore, it is recommended from this study that, the awareness of the nutritional benefits of these foods in complementary feeding should be created to communities so as to increase the utilization of these foods which will also increase the nutrient contents of complementary foods.



Key words: *Energy, protein, vitamin A, zinc, iron zinc and iron extractability in vitro protein digestibility.*

### 3.1.1 Introduction

The problem of childhood under nutrition among children of below 5 years of age remains intolerable throughout the world with large numbers of the affected children being in developing countries (UNICEF, 2009). The problem of malnutrition in many infants starts during or after introduction of complementary foods, contributing significantly to the high prevalence of malnutrition in children less than 5 years of age (Muhimbula and Zacharia 2010 and Mosha *et al.*, 2000). These studies added that majority of the infants are introduced to cereal-based complementary foods well before the recommended 6 months of age or in rare cases do not receive these until their second year of age.

Malnutrition can also be contributed by nutritionally poor quality complementary foods and insufficient amount. There are also cases in developing countries when complementary foods are of low nutritional quality and are given in insufficient amounts (Pelto and Thairu, 2003). These foods are locally produced and based on local staple foods, usually cereals that are processed into porridges (Villapando, 2000). Apart from their bulkiness reported as a probable factor in the etiology of malnutrition, cereal-based gruels are generally low in protein and are limiting in some essential amino acids, particularly lysine and tryptophan (Dewey and Brown 2003 WHO, 2001;). Tanzania as one of the developing countries is dependent on cereal and non-cereal based traditional weaning foods from maize, sorghum, millet, rice, cassava, potatoes, yams and plantains (Muhimbula and Zacharia 2010 and Mamiro *et al.*, 2005). There is a higher rate of childhood under nutrition associated with the use of these starch staples in weaning foods as reported by Mosha *et al.* (2000). In addition such foods are bulky and high in phytate, which limits the bioavailability of nutrients, including iron, calcium, zinc, and in some cases proteins, and energy which are crucial to the growth and development of infants (Gibson *et al.*, 2010).
Fortified nutritious commercial complementary foods areunavailable especially in the rural areas and whereavailable, they are often too expensive and beyond thereach of most of families in developing country like Tanzania (Dewey and brown, 2003). Given that there are many locally available nutrient dense foods which can supply enough energy, protein, vitamins and minerals

in Tanzania; there is a need to effectively utilize them so as to produce acceptable and nutrient dense porridge that can be used as complementary food in Tanzania. Therefore, this study, following the FAO/WHO/UNICEF (1971) emphasize on the use of local foods formulated in the home and guided by the following principles: (i) high nutritional value to supplement breastfeeding, (ii) acceptability, (iii) low price, and (iv) use of local food items, utilized Orange fleshed sweet potato, amaranth grains, pumpkin seeds and soybeans the locally available nutrient dense foods to develop a nutrient dense porridge flour for children (6-24) months of age and analyzed for its proximate, vitamin A and C and mineral compositions. The developed flour is expected to contribute in improving the nutritional quality of the complementary porridges in terms of energy, protein and micronutrients.

### 3.1.2 Material and methods

#### 3.1.2.1 Material

Orange Fleshed Sweet potato, Pumpkin seeds, Soy bean and Amaranth grains were selected because of their prosperity in the targeted nutrients (vitamin A in form of beta carotene, Zinc, Iron, Energy and Protein). Beside the richness of these nutrients, they are locally available and affordable since they can be adopted and produced in different places in Tanzania.Pumpkin seeds, Soy bean and Amaranth grains were purchased from Morogoro market while Orange Fleshed Sweet Potato were purchased from a farmer in Arusha region, Tanzania. Food grade chemicals and reagents for chemical analysis were obtained from the Department of Food Technology, Nutrition and Consumer science laboratory at SUA.

#### 3.1.2.2 Methods

**Research design**

Complete randomized design (CRD) was used in this study and the principal factor was formulation type. The effect of different formulations on proximate composition, mineral contents, Vitamin A and C, zinc and iron extractability, in vivo protein digestibility and viscosity of the flour and porridge samples were assessed and compared. The mathematical expression is shown in Equation 1.

$y_{ij} = \mu i + \tau_i + \varepsilon_{ij}$……………………………………………………………(i)

$i=1, 2,..., t, j=1,2,$.........................................................................................ii

Where μ is the overall mean, τi is the ith treatment effect and ε*ij* is the random effect due to jth replication receiving ith treatment.

**3.1.2.3 Preparation of orange fleshed sweet potato flour**

Orange fleshed sweet potatoes were sorted, washed, hand peeled, sliced into small chips (about 1 cm), dipped in water, then drained, spread on trays and dried for one day a in a solar drier at a temperature range of 60-65$^0$C. The dried sweet potato chips were extruded and milled into fine flour, packaged into polythene bags, sealed and stored at room temperature waiting for porridge preparation and analysis.

**3.1.2.4 Preparation of pumpkin seeds flour**

Pumpkin seeds were sorted, washed, soaked in water for one day so as to reduce amount of phytate content on the outer cover, then drained, spread on trays and dried for one day in a solar drier. The dried seeds were roasted at 100 $^0$C for 25 minutes, extruded, and milled into fine flour, packed into polythene bags and stored at room temperature.

**3.1.2.5 Preparation of soy bean flour**

Soybeans were sorted, washed boiled for 25 minutes, drained, cooled, and decupled manually, washed, spread on trays and dried for one day under solar drier. The dried soy beans were roasted, extruded, milled into fine flour, packed into a polythene bags and stored at room temperature.

**3.1.2.6 Preparation of amaranth grain flour**

Amaranth grains were collected, sorted, winnowed, washed, sprouted by soaking in water for overnight at a room temperature so as to increase digestibility and bioavailability of nutrients, cleaned, put on a tray for two days to germinate, dried by a solar drier, rubbed to remove shoots, extruded then milled into flour.

### 3.1.3 Extrusion processing of raw materials

Raw material used in making complementary food in this study were extruded co-rotating twin screw extruder with L/D ratio of 16:1 and screw diameter of 60mm, model Js-60D,China. The extrusion process was done under the following conditions: screw speed of 30rmp, feeding rate of 10.15kg/hr and barrel temperature was set at 100°C and 130°C in the first and second zones respectively. The extruded materials were collected, cooled to room temperature under natural convection conditions, milled into fine flour using milling machine (Model CH, Intermech Engineering with mesh screen of 0.8 mm), cooled, packed in polythene bags and stored at room temperature prior to porridge preparation and analysis.

#### 3. 1.3.1 Preparation of composite flour

#### 3.1.3.2 Formulations

Compositions of the formulated complementary porridge flours are shown in Table 3.1 Nutrisurvey (2007) software was used to design 12 formulations (Table 1.1) which were expected to provide at least from a half of the recommended daily allowance of the targeted nutrients which are energy (900Kcal), protein (13g), vitamin A (300µg), iron (7mg) and zinc (3mg) for children of 6-24months. From the 12 formulations, 5 formulations which provided at least from half of the recommended daily allowance of the targeted nutrients of interest in this study were taken and used in porridge making. Single flour was mixed in different proportions as shown in (Table 3.1).

**Table 3. 1: Formulations by Nutrisurvey software**

| Formulations | Soybeans (%) | Amaranh grain (%) | Pumpkn seeds (%) | OFSP (%) | Energy (Kcal) | Protein (g) | Vitamin A (µg) | Iron (mg) | Zinc (mg) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 100 | 0 | 0 | 0 | 112.6 | 32.0 | 100.0 | 3.9 | 3.1 |
| 2 | 0 | 100 | 0 | 0 | 86.0 | 13.4 | 0.0 | 7.6 | 3.2 |
| 3 | 0 | 0 | 100 | 0 | 460.0 | 24.0 | 38.0 | 12.5 | 7.0 |
| 4 | 0 | 0 | 0 | 100 | 82.0 | 6.6 | 12812. | 1.1 | 2.4 |
| 5 | 50 | 20 | 25 | 5 | 370.2 | 20.7 | 476.7 | 8.6 | 2.8 |
| 6 | 40 | 20 | 30 | 10 | 393.8 | 27.2 | 869.6 | 8.0 | 4.0 |
| 7 | 30 | 35 | 20 | 15 | 408.1 | 26.1 | 1206.4 | 7.6 | 2.8 |
| 8 | 25 | 25 | 20 | 30 | 426.0 | 24.2 | 2502.2 | 7.9 | 3.4 |
| 9 | 20 | 40 | 15 | 25 | 349.4 | 28.8 | 2120.5 | 7.0 | 2.5 |
| 10 | 15 | 25 | 30 | 20 | 316.7 | 22.2 | 1705.2 | 7.1 | 3.3 |
| 11 | 10 | 30 | 30 | 15 | 286.2 | 19.6 | 88.0 | 7.2 | 3.4 |
| 12 | 5 | 20 | 40 | 10 | 149.3 | 15.0 | 869.6 | 8.0 | 4.0 |

**Table 3. 2: formulations used in the study**

| Sample code | Soy bean (%) | Amaranth grains (%) | Pumpkin seeds (%) | OFSP (%) | Energy (Kcal) | Protein (g) | Vitamin A (µg) | Iron (mg) | Zinc (mg) |
|---|---|---|---|---|---|---|---|---|---|
| SAPO1 | 50 | 20 | 25 | 5 | 370.2 | 20.7 | 476.7 | 8.6 | 2.8 |
| SAPO2 | 40 | 20 | 30 | 10 | 393.8 | 22.7 | 869.6 | 8.0 | 4.0 |
| SAPO3 | 30 | 35 | 20 | 15 | 408.1 | 26.7 | 1206.4 | 7.6 | 2.8 |
| SAPO4 | 25 | 25 | 20 | 30 | 426.0 | 24.2 | 2502.2 | 7.9 | 3.4 |
| SAPO5 | 20 | 40 | 15 | 25 | 349.4 | 28.8 | 2120.5 | 7.0 | 2.5 |

**Reference groups: SOS: soybean, orange fleshed sweet potato and sorghum SMGM: soy bean, millet, groundnuts and maize**

#### 3.1.3.3 Porridge preparation

Seven different porridges (5 from formulated flour and 2 reference groups) were prepared by mixing 350g of flour in 1500ml of boiling water. The mixture was constantly stirred for about 15 minutes, and then 30g of sugar was added to the cooked porridge.

#### 3.1.3.4 Flour rate and viscosity determination

To determine flour rate which could provide porridge with the required viscosity (2500cP – 3000cP) as given by Thaoge *et al.* (2003) and Mosha and Svanberg, (1983). Different flour rates of formulated and control groups were tried as shown in Table 6. Flour rate of 350g was selected to be mixed with 1500ml water to prepare porridge since it provided the viscosity which was within the recommended viscosity for infant feeding.

### 3.1.4 Chemical analyses

#### 3.1.4.1 Determination of Protein

Protein was determined by Kjeldahl method using standard AOAC Method (2000). About 2g of dried samples were taken in digestion flask then 10-15 ml of concentrated $H_2SO_4$ and 8g of digestion mixture i.e. $K_2SO_4$: $CuSO_4$ (8:1) was added. The flask were swirled in order to mix the contents thoroughly then placed on the heater for about 2 hours to start digestion till the mixture became (blue green color). The digest was cooled and transferred to 100 ml volumetric flask and volume made up to mark by the addition of distilled water. 10 ml of the digest was introduced in the distillation tube then 10 ml of 0.5 N NaOH was gradually added.

Distillation was continue for at least 10 minutes and $NH_3$ produced was collected as $NH_4$ OH in a conical flask containing 20 ml of 4% boric acid solution with few drops of modified methyl red indicator. During distillation yellowish color appeared due to NH4 OH. The distillate was then titrated against standard 0.1 N HCL solutions till the pink color appeared.

The percentage of protein was calculated using the following formula

$\%\text{Protein} = 6.25 * \%\text{N}(* \text{Correction factor})$……………………………….eqn i

$\%\text{N} = (\text{SB}) * 0.014 * \text{D} * \frac{100}{\text{Weight}}$ of the sample…………………………….....eqn. ii

Where. S is Sample titration reading, B is blank titration reading, N is =normality of HCL, D is=dilution of sample after digestion, V=Volume taken for distillation and 0.014=Mill equivalent weight of Nitrogen

### 3.1.4.2 Determination of Fat

Fat determination was carried out according to AOAC (1999) method 945.87 Soxhlet ether extraction using the Soxhlet extractor. During the process the Soxhlet extractor was fitted up with 150ml of Petroleum spirit (40 – 60$^{o}$C). Then a 5g of a sample potion was accurately weighed into an extraction thimble that previously dried in an oven. The thimble was then pluged lightly with cotton wool and placed in the extractor. The condenser of the Soxhlet extractor was replaced with the heating mantle while making sure that the joints are tight. The source of heat was then adjusted such that the solvent boiled gently and be able to siphon over for about three hours. Then the condenser was detached and the thimble removed. In addition to that the round bottomed flask containing the solvent and the extracted fat was detached. Solvent and fat are separated by using the rotary vacuum or water bath (Wagtech, Laborota 4001, Uk) in a fume hood, the flask was placed in the oven at 100$^oC$ and dried to constant weight. The flask was then cooled in the desiccator and weighed after cooling. Then the extracted fat was determined using the formula;

Percentage fat (%Fat) = $\frac{(Weight of Cup + EE) - Weight of empty cup}{Sample weight} x\ 100$

Where: EE =*Ether extract / fat content*

**3.1.4.3 Determination of Crude fiber**

Crude fibre was determined according to AOAC (1990) Method No. 14:020 through hot digestion with acid and alkali solutions. A bottle with reagents (sulphuric acid) was placed on a hot plate and heated to a temperature of 95 to 100$^oC$. The samples were loaded on the weighed crucibles, locked in position with a handle and placed in front of the radiator in the hot extraction unit while ensuring the safety latch engaged. Then the reflectors were placed in front of the crucibles and valves turned off. The cold water tape for the reflux system was opened and the main button pressed to start the extractor. Hot extraction was then carried out by pouring reagents into the columns from the top using a funnel to the mark (100mls/150mls/200mls). The heater was switched on and then three drops of anti-foaming agent (n-octanol) were added in each column. The boiling speed was moderated by using the heater control. While extraction going on distilled water and sodium hydroxide solution were heated in beaker and bottle respectively. By the end of extraction the heater was turned off, the water suction pump was started and the valves pressed to vacuum position. The sample containing crucibles were then washed three times with hot water using special water sprayer followed by drying them. The operation was then repeated from step one for the second extraction with sodium hydroxide solution. The crucibles were then released from the extractor using a safety hook. Using crucible holder, the crucibles were transferred to the cold extraction unit. Then the crucibles washed three times with acetone contained in the wash bottle. Crucibles contained samples were dried in an oven at 100$^oC$ and then taken to the desiccators. After cooling the crucible in the desiccators, crucibles and sample were reweighed and final weights recorded. The percentage fibre content on both dry and wet basis was then calculated following the formula;

Crude fibre (on wet basis) = $\frac{Weight of crucible\ and\ dry residue - Weight of crucible\ and\ Ash}{Sample\ weight}$ x 100

Crude fibre (on dry basis) = $\frac{\%\ fibre on wet basis}{\%\ Dry matter}$ x 100

**3.1.4.4 Dry Matter and moisture content determination**

Moisture content was determined according to Tomohiro (1990), whereby 5g of samples (porridge and flour) were taken and placed on a dry Petri dish of known weight and weighed. Thereafter, the sample on the petri dish was taken to the oven preset at 110$^{o}$C for drying for about 5 hours. The sample was then cooled in the desiccator and weighed again.

After every four hours of oven drying, the sample was taken out of oven, cooled in the desiccators and weighed. The process repeated till a constant weight was attained. Percentage moisture content was then calculated using the following formula.

$$\%\ MC = \frac{(Dish + sample\ before\ drying) - (dish + sample\ after\ drying)}{(Dish + sample\ before\ drying) - Empty\ dish} x\ 100$$

**3.1.4.5 Determination of total carbohydrates content**

The carbohydrate content was determined by difference on dry weight basis.The total percentages of the fat, crude protein, ash, dietary fibre were deducted from 100%, the remainder accounts for carbohydrate content.

On dry weight basis

$$\%\ \text{Carbohydrate (CHO)} = 100\ \% - (\%\ \text{Fat} + \%\ \text{Ash} + \%\ \text{dietary Fibre} + \%\ \text{Crude Protein})$$

### 3.1.5 Vitamins determination

#### 3.1.5.1 Vitamin C (Ascorbic acid) determination

A weight of 2g of porridge and flour was measured using weighing scale; 10ml of 10% Trichloroacetic acid (TCA) solution was added. The mixture was shaken for few minutes and left to extract the contents, the extracted solution was then diluted to 50ml with excess 10% TCA solution and filtered using No. 1 Whatman filter papers. 10ml of the filtrate was taken into 250ml conical flask and titrated with standard solution of 2,6-Dichlorophenolindophenol, Sodium salt until faint pink colour obtained which persist for10 seconds. (Tomohiro, 1990). The Vitamin C content was then calculated using the formula below:

$$\text{Vitamin C content in mg/100g of the sample} = \frac{(A - B) * C * V * 100}{D * S}$$

Where, A is volume in ml of the Indophenols solution used for sample, B is volume in ml of the indophenols solution used for blank, C is mass in mg of ascorbic acid equivalent to 1.0ml indophenols solution, S is mass of sample in (g) taken for analysis and V = total volume of extract in milliliters

#### 3.1.5.2 Beta carotene determination

Beta carotene determination was done according to Delia and Mieko (2004) whereby 0.2- 0.3g of a flour and 5g of porridge were measured and homogenized 4 times using 50mls proportions of cold acetone before extracted. The extract was transferred into the separating funnel contained petroleum ether (40-60$^{o}$C Bp), followed by a thorough washing with about 300mls of distilled water until the extracts were acetone free. During the washing process, the distilled water was put along the walls of the glass separating funnel to avoid formation of emulations (water stones) in the carotenoid extracts. The washed samples were then passed through anhydrous sodium sulphate to make it free from any trace of water. The dried carotene extracts was then collected into a clean and dry volumetric flask. Beta carotene stock standard solution with the concentration of 100µg/ml was prepared. This stock solution diluted serially to obtain 0, 0.25, 0.5, 1.0, 2.0, 4.0, 6.0, 8.0, 10.0 and 12.0 µg/ml concentrations. The extract and diluted standards was then read under UV-Visible Spectrophotometer Wagtech, CECIL 2021 at 450nm to obtain its optical density (OD) which was able to estimate the Beta carotenes in the sample. Linear regression equation obtained from the standard plot and the beta carotene content of the unknowns calculated as described by (Rasaki *et al*., 2009).

#### 3.1.5.3 Determination of mineral content

The analysis of minerals was done according to the AOAC (1999) procedures by the use of UNICAM, 919 Atomic Absorption Spectrophotometer (AAS). Samples were dried and then ashed at 450 $^{0}$C under a gradual increase of 50$^{0}$ C temperature per hour.

#### 3.1.5.4 Iron and zinc solubility

Iron and zinc solubility were determined using a method by Duhan *et al*. (2002). The minerals in the samples (1.0 g) were extracted with 10 ml of 0.03 N HCl by shaking at 37 °C for 3 h. The mixture was filtered with Whatman # 42 filter paper and was oven dried at 100 °C and wet acid digested. The amounts of the HCl-extractable zinc and iron in the digested samples were determined following procedures for mineral determination.

$$Mineral\ extractability\ \% = \frac{Mineral\ extractable\ in\ 0.03N\ Hcl}{Total\ mineral} \times 100$$

### 3.1.6 Nutrient density determination

Porridges were prepared at different flour ratio (200g, 250g, 300g, 350g and 400g) in 1500ml hot water. The viscosities of these porridges were measured using HAAKE viscometer 2 plus version 1.5. Flour rates of the porridges were determined to know which the flour rate could give the porridge with acceptable viscosity (2500-3000Cp) (Thaoge *et al.*, 2003). After obtaining the flour rate with acceptable viscosity, the energy, protein, iron, zinc and vitamin A densities of all porridge samples were calculated based on the flour rate obtained. The nutrient densities of the porridge samples were calculated using the formulae;

$$\text{Nutrient density (100 ml)} = \frac{\text{Flour rate}}{\text{100 ml}}\ \text{x Nutrient/100 g}$$

### 3.1.7 In *vitro* protein digestibility

In *vitro* protein digestibility was determined according to the method explained by Tilley and Brit (1961). About 5g g of porridge and flour samples were dried and digested anaerobically with rumen microorganism at 38$^oC$ for 48hr. The samples were dried in the oven for 6 hours at 100$^0C$ and grounded to pass 0.8mm sieve. The buffer solution was made up according to the formula for synthetic saliva of Dougall (1948) adding the $CaCl_2$ last the solution is thoroughly saturated with $CO_2$ at 38$^0C$ until it became clear. The samples were put in the test tubes, mixed with rumen liquor and buffer solution, stirred and gassed with carbon dioxide. The tubes were incubated at 38$^oC$ in the dark for 48 hours, being shaken 3 to 4 times a day by hand. The tubes were centrifuged immediately for 15mins, and then the supernatant was discarded. After discarding the supernatant, 50 ml of freshly-made pepsin solution was added to the residues. The tubes were then incubated at 38$^oC$ for 48hours with occasional shaking. After incubation, supernatants were discarded and insoluble residue was washed with water. The tubes with residues were dried at 100$^0C$ so as to get the dry weight of the samples. Digestibility is weight of digestible material in 100g of herbage dry matter. After all these procedures the in vitro dry matter digestibility (%) was calculated by formula below;

$$IVDMD=\frac{100*(\text{Sample dry matter}) - (\text{residual dry matter-residue . Incubated reagent blank})}{\text{Sample dry matter}}$$

### 3.1.8 Statistical data analysis

The data were analysed by using R statistical package (R Development Core Team, Version 3.0.0, Vienna, Austria) for one-way analysis of variances to determine the significant differences between the factor means at ($p<0.05$). Means were separated by Turkey's Honest Significant Difference at $p <0.05$. Results were presented in tabular form as mean ±SD

### 3.1.9 Results

#### 3.1.9.1 Proximate composition

Proximate composition of the formulated flour and porridges together with two references (SOS and SMGM) are given in Tables 3.3.1 and 3.3.2. There were significant differences ($p<0.05$) in proximate parameters between the samples with reference sample SMGM having higher values of 8.4 and 83.8 g/100 g of moisture content in both flour and porridge respectively, while SAPO1 had significantly lower respective values of 4.9 and 77.0 g/100 g. SAPOF1 and SAPO1 had significantly higher protein contents of 4.4 and 5.3) in both flour and porridge. SAPOF1had higher fat content of 24.8 g than the reference group SOSF with value of 2.6 g/100g, while in porridges SMGM had a higher fat content of 2.1 g/100 g than other samples. Furthermore, reference SOSF and formulation SAPO1 had significantly higher carbohydrate contents than the other samples.

**Table 3.3. 1: Proximate composition of flours samples**

| Sample | Proximate composition g/100 g DM | | | | | |
|---|---|---|---|---|---|---|
| | Moisture (%) | Protein (%) | Fat (%) | Fibre (%) | Ash (%) | CHO (%) |
| **SOSF** | $7.7±0.172^{b}$ | $1.3±0.006^{e}$ | $2.6±0.014^{g}$ | $0.1±0.001^{c}$ | $0.1±0.001^{c}$ | $88.1±0.211^{a}$ |
| **SMGMF** | $8.4±0.212^{a}$ | $1.4±0.007^{e}$ | $6.1±0.043^{f}$ | $0.1±0.006^{c}$ | $0.1±0.001^{c}$ | $77.7±0.260^{b}$ |
| **SAPOF1** | $4.9±0.429^{e}$ | $5.3±0.007^{a}$ | $24.8±0.006^{a}$ | $0.2±0.007^{b}$ | $0.2±0.001^{b}$ | $64.9±0.436^{e}$ |
| **SAPOF2** | $4.9±0.369^{e}$ | $4.9±0.007^{b}$ | $23.8±0.007^{b}$ | $0.2±0.014^{b}$ | $0.3±0.004^{a}$ | $65.8±0.352^{e}$ |
| **SAPOF3** | $5.6±0.417^{d}$ | $3.7±0.014^{c}$ | $18.6±0.064^{c}$ | $0.2±0.007^{b}$ | $0.2±0.007^{b}$ | $71.7±0.509^{d}$ |
| **SAPOF4** | $6.1±0.311^{c}$ | $3.0±0.063^{d}$ | $15.9±0.028^{d}$ | $0.3±0.007^{a}$ | $0.2±0.007^{b}$ | $77.7±0.049^{b}$ |
| **SAPOF5** | $6.1±0.025^{c}$ | $3.2±0.001^{d}$ | $12.8±0.011^{e}$ | $0.2±0.011^{b}$ | $0.2±0.007^{b}$ | $74.4±0.402^{c}$ |

**Means in each column with different superscripts are significantly different (P<0.05 (SAPOF1-5, SOSF and SMGMF) = Flours**

**Table 3.3. 2: Proximate composition of porridges g/100g**

| Sample | Moisture (%) | Protein (%) | Fat (%) | Fibre (%) | Ash (%) | CHO (%) |
|---|---|---|---|---|---|---|
| **SOSP** | $83.6±0.311^{a}$ | $1.4±0.007^{f}$ | $1.6±0.07^{b}$ | $0.1±0.001^{d}$ | $2.3±0.046^{d}$ | $11.0±0.349^{d}$ |
| **SMGMP** | $83.8±.003^{a}$ | $1.6±0.006^{e}$ | $2.1±0.004^{a}$ | $6.3±0.071^{a}$ | $1.9±0.201^{e}$ | $4.2±0.260^{e}$ |
| **SAPOP1** | $77.0±1.382^{d}$ | $4.4±0.021^{a}$ | $0.7±0.007^{e}$ | $0.2±0.007^{bc}$ | $2.7±0.135^{bc}$ | $15.0±1.497^{a}$ |
| **SAPOP2** | $80.5±0.131^{bc}$ | $4.3±0.007^{a}$ | $0.6±0.007^{f}$ | $0.2±0.014^{c}$ | $3.1±0.069^{ab}$ | $11.2±0.482^{d}$ |
| **SAPOP3** | $78.9±0.198^{cd}$ | $3.8±0.007^{b}$ | $0.9±0.007^{d}$ | $0.2±0.007^{bc}$ | $3.5±0.402^{a}$ | $12.8±0.437^{c}$ |
| **SAPOP4** | $79.1±0.485^{c}$ | $2.7±0.014^{d}$ | $0.9±0.007^{d}$ | $0.3±0.007^{b}$ | $3.2±0.344^{b}$ | $13.4±0.069^{b}$ |
| **SAPOP5** | $81.4±0.307^{b}$ | $3.1±0.007^{c}$ | $1.2±0.042^{c}$ | $0.2±0.011^{bc}$ | $2.8±0.223^{c}$ | $11.9±0.104^{cd}$ |

**Means in each column with different superscripts are significantly different (P<0.05 (SAPOP1-5, SOSP and SMGMP) = Porridges**

Tables 3.4.1 and 3.4.2 show Beta-carotene and vitamin C contents of flour and porridge samples in both references and formulated samples. SAPOF5 and SMGMP had a significantly (P<0.05) higher vitamin C contents of 7.8 and 4.6 mg/100 g respectively. SAPOF4 had significantly higher beta carotene content of 232.2 µg/100g in flour samples while in porridges was 96.4 µg/100g.

**Table 3.4. 1: Beta- carotene and Vitamin C of flour samples**

| | Vitamins | |
|---|---|---|
| **Sample** | **Vitamin C (mg/100g)** | **Beta carotene (µg/100g)** |
| **SOSF** | $1.6 \pm 0.007^{e}$ | $215.5 \pm 0.39^{c}$ |
| **SMGMF** | $2.2 \pm 0.007^{d}$ | $148.5 \pm 0.06^{g}$ |
| **SAPOF1** | $1.6 \pm 0.007^{e}$ | $180.5 \pm 0.56^{f}$ |
| **SAPOF2** | $2.1 \pm 0.007^{d}$ | $186.4 \pm 0.85^{e}$ |
| **SAPOF3** | $4.4 \pm 0.007^{c}$ | $197.1 \pm 0.16^{d}$ |
| **SAPOF4** | $7.8 \pm 0.007^{a}$ | $232.2 \pm 0.00^{a}$ |
| **SAPOF5** | $7.5 \pm 0.007^{b}$ | $224.5 \pm 0.66^{b}$ |

**Means in each column with different superscripts are significantly different (P<0.05) (SAPOF1-5, SOSF and SMGMF) = Flours.**

**Table 3.4. 2: Beta-carotene and Vitamin C of porridge samples**

| **Sample** | **Vitamin C (mg/100g)** | **Beta carotene (µg/100g)** |
|---|---|---|
| **SOSP** | $2.9 \pm 0.007^{c}$ | $49.6 \pm 0.28^{e}$ |
| **SMGMP** | $4.6 \pm 0.007^{a}$ | $37.5 \pm 0.32^{g}$ |
| **SAPOP1** | $1.5 \pm 0.007^{f}$ | $41.2 \pm 0.17^{f}$ |
| **SAPOP2** | $2.1 \pm 0.007^{e}$ | $66.2 \pm 0.16^{d}$ |
| **SAPOP3** | $2.5 \pm 0.007^{d}$ | $70.5 \pm 0.15^{c}$ |
| **SAPOP4** | $3.9 \pm 0.007^{b}$ | $96.4 \pm 0.25^{a}$ |
| **SAPOP5** | $0.9 \pm 0.007^{g}$ | $78.6 \pm 0.15^{b}$ |

**Means in each column with different superscripts are significantly different (P<0.05 (SAPOP1-5, SOSP and SMGMP) = Porridges**

Tables 3.5.1 and 3.5.2 show the minerals composition of porridge samples in both formulated and references. SAPOP2 had a highest zinc value of 12.1 mg/100g while SOSP had lowest of 4.1mg/100g, SAPOP3 had a significant higher ($p<0.05$) iron content of 24.2 mg/100g while SOSP had lowest value of 6.5 mg/100g.

Sodium content was higher in SAPOP2 269.7 mg/100g SOSP had the lowest 102 mg/100g sodium content. SAPO2 had higher 83.8 mg/100g calcium compared to SOSP which had the lowest 37 mg/100g calcium content. SAPOP3 had significantly higher 237 mg/100g while SMGM had the lowest 92mg/100g magnesium content. SAPOP3 had a highest 292 mg/100g while SMGM had lowest 148 mg/100g phosphorus content.

**Table 3.5 : Mineral composition of the porridge samples**

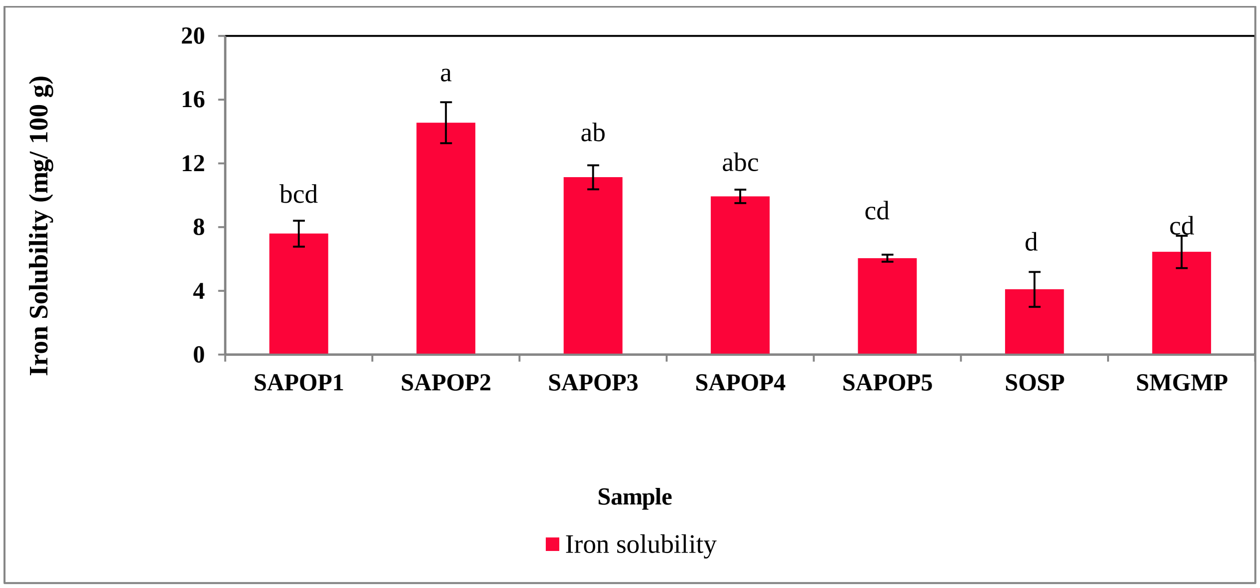
| | **Mineral composition g/100 g DM** | | | | | |
|---|---|---|---|---|---|---|
| **Sample** | **Zn** | **Fe** | **Na** | **Ca** | **Mg** | **P** |
| SAPOP1 | 9.5 ±2.74$^{b}$ | 18.4±5.46$^{b}$ | 153.5±7.91$^{d}$ | 70.5±3.86$^{b}$ | 186.6±3.86$^{c}$ | 301.6±4.07$^{a}$ |
| SAPOP2 | 11.3 ±1.86$^{a}$ | 24.2 ±2.78$^{a}$ | 269.7±4.82$^{a}$ | 83.8±2.93$^{a}$ | 218.7±3.32$^{b}$ | 259.3±2.88$^{c}$ |
| SAPOP3 | 12.1±1.17$^{a}$ | 18.4 ±2.99$^{b}$ | 253.7.±2.93$^{b}$ | 63.5±4.64$^{c}$ | 231.0± 3.46$^{a}$ | 292.4 ±4.30$^{b}$ |
| SAPOP4 | 7.3 ±1.58$^{c}$ | 15.2 ±2.03$^{c}$ | 193.2±3.36$^{c}$ | 46.4±2.62$^{f}$ | 176.7±2.18$^{d}$ | 157.9 ±2.60$^{e}$ |
| SAPOP5 | 7.1 ±0.32$^{c}$ | 13.4 ±6.37$^{cd}$ | 147.2±4.45$^{e}$ | 49.6±3.08$^{e}$ | 168. 2±5.37$^{e}$ | 165.7±3.13$^{d}$ |
| SOSP | 4.1±1.06$^{e}$ | 6.5 ±6.204$^{e}$ | 102.7±2.66$^{g}$ | 37.5±2.37$^{g}$ | 100.2 ±2.06$^{f}$ | 157.1±3.00$^{e}$ |
| SMGMP | 5.3±1.71$^{d}$ | 10.9 ±2.44$^{d}$ | 116.9±2.35$^{f}$ | 58.2±1.19$^{d}$ | 92.9 ±2.58$^{g}$ | 148.6±5.85$^{f}$ |

### 3.1.9.2 Iron and zinc solubility of the porridge samples

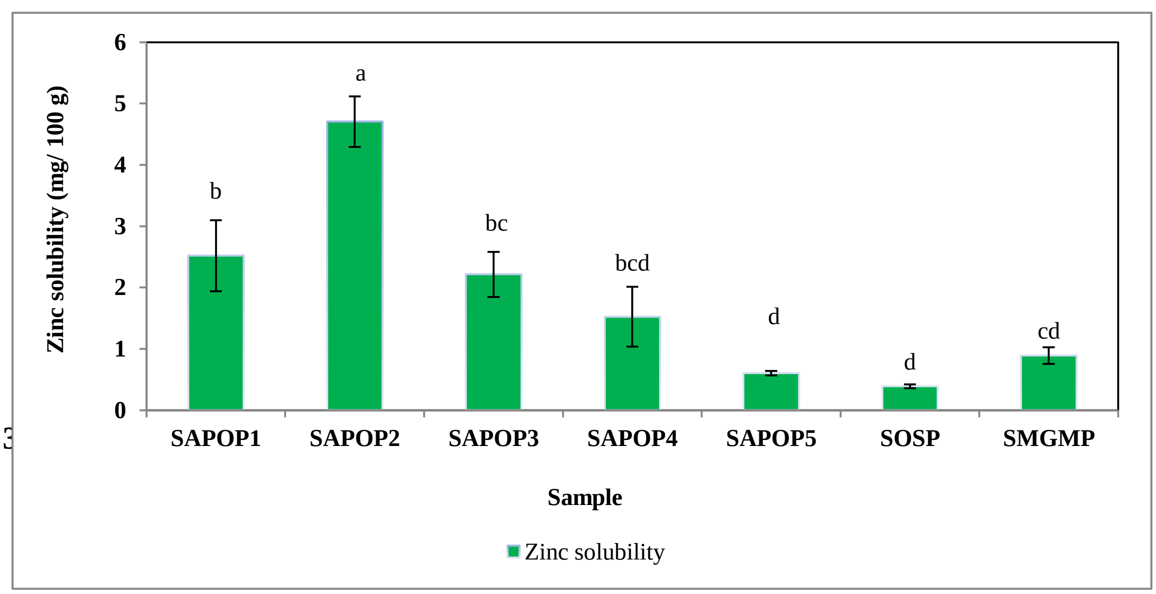
As for zinc and iron solubility, there were a significant ($p < 0.05$) differences between samples (Figures 6 A and B). SAPOP2 had significantly ($p<0.05$) higher mean scores of 14.5 mg/100g and 4.7 mg/100g for both Iron and Zinc solubility while SAPOP5 had lower scores of 6.4 and 0.6 mg/100g respectively.

**Figure 6: A and B: Iron and Zinc solubility (mg/100g)**

**(A) Iron solubility of porridge samples**




**(B) Zinc solubility of porridge samples**



Different flour rates used are shown in (Table 3.6) whereby five flour rates were tried to determine the flour rate which could produce porridge with acceptable viscosity (2500-3000cP). Among the flour rates tried 300 g and 350 g produced acceptable viscosity for child feeding. Therefore, 350 g was selected to be used as the flour rate in this study.

***Table 3.6 : Flour rates and viscosities of porridge samples***

| **Sample** | **Flour rate (g)** | **Viscosity (cP)** |
|---|---|---|
| Formulated flour | 200 | 1950 |
| | 250 | 2179 |
| | 300 | 2786 |
| | *350 | 3043 |
| | 400 | 4500 |
| Control groups | | |
| 1 | 350 | 4658 |
| 2 | 350 | 6598 |

Viscosity measurements were carried out at 50°C.

#### 3.1.9.4 Energy contents

Table 3.7 shows the contribution of carbohydrate, protein and fat to the energy content of the porridge. The energy content was calculated by using the Atwater general factor system which is based on the heats of combustion of protein, fat and carbohydrate. The energy values used are 4.0 Kcal/g for protein, 9.0 Kcal/g for fat and 4.0 Kcal/g for carbohydrate.

**Table 3.7 : Energy contribution from protein, fat and carbohydrate**

| Sample | Protein (g) | Fat (g) | Carbohydrate (g) | Energy (kcal/100g | % E from protein | % E from fat | % E from CHO | Total energy |
|---|---|---|---|---|---|---|---|---|
| **SOSP** | 1.4 | 1.6 | 11 | 64 | 8.75 | 22.5 | 68.75 | 100 |
| **SMGMP** | 1.6 | 2.1 | 4.2 | 42.1 | 15.20190024 | 44.8931116 | 39.90498812 | 100 |
| **SAPOP1** | 4.4 | 0.7 | 15 | 83.9 | 20.97735399 | 7.50893921 | 71.51370679 | 100 |
| **SAPOP2** | 4.3 | 0.6 | 11.2 | 67.4 | 25.51928783 | 8.01186944 | 66.46884273 | 100 |
| **SAPOP3** | 3.8 | 0.9 | 12.8 | 74.5 | 20.40268456 | 10.8724832 | 68.72483221 | 100 |
| **SAPOP4** | 2.7 | 0.9 | 13.4 | 72.5 | 14.89655172 | 11.1724138 | 73.93103448 | 100 |
| **SAPOP5** | 3.1 | 1.2 | 11.9 | 70.8 | 17.51412429 | 15.2542373 | 67.23163842 | 100 |

**SAPOP1-5= Formulations SOSP and SMGMP= References**

Table 3.8 shows the expected amount of the nutrients that will be available in the porridge when 100 ml of each of the porridge will be consumed. SAPO1 had higher 117.61 Kcal and 3.19 g of energy and protein densities, SAPO4 had highest beta-carotene density of 56.11µg while SAPO2 had highest densities of 14.5 and 4.7 mg for both iron and Zinc respectively.

**Table 3.8 : Nutrient density of 100ml of the formulated porridge**

| Sample | Energy density(Kcal) | Protein density(g) | Vitamin A density(µg) | Iron density(mg) | Zinc density(mg) |
|---|---|---|---|---|---|
| **SAPO1** | 117.61 | 3.19 | 45.99 | 7.5 | 2.5 |
| **SAPO2** | 115.97 | 3.17 | 43.16 | 14.5 | 4.7 |
| **SAPO3** | 109.43 | 2.13 | 47.94 | 11.2 | 2.7 |
| **SAPO4** | 108.71 | 1.11 | 56.11 | 9.9 | 1.5 |
| **SAPO5** | 109.31 | 3.11 | 53.51 | 6.0 | 0.6 |

### 3.1.9.5 In *vitro* protein digestibility

The in *vitro* protein digestibility for flour and porridge samples which represent the available protein for body`s nourishment when this porridge is consumed is shown in Table 14. Formulated products had higher in vitro protein digestibility than control groups.

**Table 3.9. 1: In *vitro* protein digestibility of flour samples**

| Sample | % In vitro protein digestibility |
|---|---|
| SAPOF1 | 99.8±0.007[a] |
| SAPOF2 | 99.8±0.021[ab] |
| SAPOF3 | 99.8±0.064[a] |
| SAPOF4 | 99.9±0.010[a] |
| SAPOF5 | 99.8±0.035[ab] |
| SMGMF | 93.9±0.007[c] |
| SOSF | 90.9±0.014[d] |

**Means in each column with different superscripts are significantly different (P<0.05). SAPOF1-SOSF= flours**

**Table 3.9. 2: In *vitro* protein digestibility of porridge samples**

| Sample | % In *vitro* protein digestibility |
|---|---|
| SAPOP1 | 99.8±0.000$^{ab}$ |
| SAPOP2 | 99.8±0.014$^{b}$ |
| SAPOP3 | 99.8±0.173$^{a}$ |
| SAPOP4 | 99.8±0.007$^{ab}$ |
| SAPOP5 | 99.8±0.014$^{b}$ |
| SMGMP | 92.9±0.007$^{c}$ |
| SOSP | 90.9±0.014$^{d}$ |

**Means in each column with different superscripts are significantly different (P<0.05) SAPOP1-SOSP=Porridges**

### 3.1.9 DISCUSSION

#### 3.1.9.1 Proximate composition

The significant (P<0.05) difference observed in moisture content between samples could be associated with differences in ingredient rations among formulations. The observed difference in moisture contents between formulations and references predicts the shelf life of this flour. This means that, formulations with lower 4.9% moisture content will be having longer shelf life than that with 8.4% since high moisture content encourages microbial growth. Even though the moisture content in reference flours was high, it is still within the recommended limit (below the maximum limit of 15%) as reported by Victor *et al.*, (2013) and WFP, (2012).

The significant higher (P<0.05) protein content reported in formulations compared to control groups was associated with addition of amaranth grains and pumpkin seeds. The observed variation in protein within formulations could be due to differences in soybean ratio, as the protein content decreased with decreased soybean ratio. The highest 5.3% protein content in SAPOF1 could be due to its higher amount of soybean compared to other formulations. This observation correlates with other studies by Dixit *etal.*,(2011) and Laswai *et al.*, (2010) that showed the contribution of soybean of up to 38% of protein in foods. The reported variation in protein within formulations was also attributed by amaranth grains. The increase ratio of amaranth grain in SAPOP5 led to increased 3.1% of protein contents than in SAPOP4 with 2.7%. This observation is similar to the results found by Olamide, (2015); Muyonga *et al.* (2014) that showed the amaranth based instant porridge satisfied the protein of up to15g/100 g. The studies added that consideration of the amaranth grains to the complementary foods at a reconstitution of only 20% amaranth grain would meet 87.46% protein requirement of children under five years old. The observed slight decrease in protein content in porridge samples compared to flour could be associated to partial removal of some amino acids and other indigenous compound as a result of cooking effect (Hassan *et al.,* 2005; and Rehmanand 2005).

The reported differences in fat content between control groups and formulations as well as within formulations were associated to soybean ratio, inclusion of amaranth grains and pumpkin seeds. The significant (p<0.05) higher fat content (24.8%) observed in SAPOF1 could be attributed higher amount of soybean compared to other formulations. This observation is in line with others studies by Ngozi, *et al*., (2014) and Ojinnaka *et al.*, (2013) that showed soybean as oil seed contains a lot of fat (21.7%), and explained that the higher the inclusion of soybean flour the higher the fat content of the products. They added that protein and fat levels in formulations are increased with the increased ratio of soybean flour. The observed results also agreed with the study done by Solomon (2005) who explained that when vegetable oils were included in infant and children foods they not only increased energy density, but also fat which is a transport vehicle for fat soluble vitamins. The reported range of 12.8%-24.8% fat content in the formulations was less than the recommended values of 30% - 45% fat which should be supplied by complementary foods for its contribution to total energy requirement for children aged 6-24 months (Brown and Dewey, 2003). The results also revealed the decreased fat content within formulations was associated with the decrease of soybean ratio.

The higher ash content for formulations of 3.1, 3.5 and 3.2 for SAPOP2, SAPOP3 and SAPOP4 respectively were above the recommended level of 3% (WPF, 2012). The observed high ash content could be associated with the increased ratio of pumpkin seeds in those formulations and implies the availability of higher minerals contents in those formulations since ash content reflects mineral content of the products These findings are similar to a study by Hamed *et al*, (2008) which showed the higher ash content of 9.04 and 8.78 for both unroasted and roasted pumpkin seeds respectively.

The carbohydrate contents observed in formulations and control groups could be associated with the differences in ingredients and ingredient ratio used. Carbohydrate content was increasing as the ratio for amaranth grains, pumpkin seeds and orange fleshed sweet potato were increasing. This observation correlated with other studies by Waized *et al*. (2015) Muyonga *et al.* (2014 and Revathy and Sabitha (2013) on amaranth grains, pumpkin seeds and orange fleshed sweet potato that reported the contribution of these foods to the carbohydrate content.

#### 3.1.9.2 Beta carotene and Vitamin C

The significant variation in Vitamin A (beta carotene) between formulation and control groups and specifically higher value of 232.5 µg/100g in SAPO4 could be ascribed to its highest ratio of orange fleshed sweet potato compared to other formulations. This effect was expected because the main reason of selecting OFSP in this study was its contribution of vitamin A in form of beta carotene. This was supported by a study done by Waized *et al*. (2015) which showed that only 125g of most OFSP varieties could supply the recommended daily allowance of vitamin A for children and lactating mothers. However, the obtained value of 232.5µg/100g is below RDA of vitamin A of (500µg and 300µg) for children 6-12 months and 12-23 months respectively (Lwelamira *et al.* 2013; Lutter, 2013; FAO, 2011; Lutter and Dewey 2003). Therefore, in order for the children to meet the RDA they must be supplied with vitamin A from other sources such as breast milk, and other foods apart from the porridge.

Although the OFSP was mainly targeted to supply vitamin A (beta –carotene) in this study, the beta carotene content reported in the formulated foods was not only provided by orange fleshed sweet potato but also from pumpkin seeds and amaranth grains. This is because apart from their primary nutrients, pumpkin seeds and amaranth grains can contribute to the vitamin content of their products. This is similar to studies by Revathy and Sabitha, (2013) and Maria *et al.*(2012) that found the presence of 1180µg/100g and 80IU of beta carotene in pumpkin seed flour. Other studies by Okoth *et al.* (2016) and Muyonga *et al.* (2014) have reported the presence of vitamin A in grain amaranth.

The vitamin C content in foods also helps in absorption of iron from the food. The observed difference in vitamin C content between formulations and control groups was associated with increased ratio of orange fleshed sweet potato in formulations. The results revealed that vitamin C was increasing as OFSP ratio was increasing. This is because apart from vitamin A, OFSP also provides other vitamins such as Vitamin C, E and K. The significant ($p<0.05$) higher (7.8mg/100g) vitamin C content in SAPOF4 was attributed by increased ratio of OFSP than in other formulations. This observation correlated with a study done by Waized *et al.* (2015)which showed the presence of vitamin C in OFSP.

**3.1.9.3 Iron and Zinc solubility**

The iron and zinc contents and their solubility observed from the porridge samples were mainly supplied by pumpkin seeds. The observed higher 57.3 mg/100g extractable iron in SAPOP4 could be attributed by pumpkin seeds and orange fleshed sweet potato ratio. The increased ratio of OFSP in formulation SAPO4 contributed to increased soluble iron. This observation is similar to the study done by Christide *et al.*(2015) which found that Orange fleshed sweet potato based complementary foods had more bio- available iron. The observed range (27.9 to 57.3 mg/100g) of iron solubility in porridge samples were higher than the amount of iron (7 mg) which is required for daily supply to children aged 6-24 months. This range is also higher than 17.3mg/100g found in a pumpkin seed flour, reported by Hassan *et al.,* (2008). The range also differed from 4.5mg/100g reported by Glaml *et al.* (2005); and 10.9 mg/100g reported by El-Adawy and Taha (2001). This variation is attributable to ingredients used, varieties of foods used as well as processing methods used.

The reported high (4.7 mg/100g) zinc solubility in SAPOP2 compared to (0.6 mg/100g) in SAPOP5 is contributed by the increase of pumpkin seed ratio. This is because SAPO2 had a higher pumpkin seed ratio compared to other formulations. The decreased zinc extractability in SAPOP5 was related to the decrease ratio of pumpkin seeds. The observed high mean score of zinc extractability in this study was 4.7 which is higher than the recommended daily allowance of 3 mg of zinc needed for children of 6-24 months. The observed score was also higher compared to 3.7 mg/100g reported by Echessa *et al.* (2013).

The observed differences in mineral extractability in this study and that of other studied might be contributed by ingredients used, plant varieties, processing methods as well as total mineral content after processing (Hassan *et al.*, 2008). Also it is similar to studies by Singh *et al.* (2007) and Alonso *et al.* (2001) that extrusion cooking process improved mineral bioavailability in the products by reducing other factors that inhibit absorption of minerals. Therefore the observed higher ranges of iron and zinc extractability in this study can also be associated with an effect of extrusion cooking method involved.

#### 3.1.9.4 Flour rate and viscosity of porridge

Viscosity is an important aspect to be considered in infant feeding since it determines the nutrient intake of the food and even affect taste intensity of the food (Mburu *et al.*, 2011). Although the same amount of water was used for control group and formulated flour, the control group porridge samples attained higher 4658cP and 6598cP than recommended viscosity for infant feeding. This could be attributed to the use of cereals as main or part of ingredients in complementary porridge. Studies by Michaelsen and Friis (1998); and Muhimbula and Zacharia, (2010) have explained higher bulkiness contributes to higher viscosities in cereal based complementary foods. Together with this, extrusion cooking process contributed to lower viscosity for formulated products compared to control groups. This observation has also been reported in other studies by Hagenimana *et al.* (2006) and Ritruengdech *et al. (*2011) that showed lower viscosity of extruded flour than unextruded one.  Moreover, in their studies, Onyango *et al.* (2004) and Magala-nyago *et al.* (2005) reported that extrusion cooking has been used to reduce viscosity in order to increase energy density of gruels.

#### 3.1.9.5 Contribution of the nutrients composition of the formulated porridge to the nutrient requirement of children 6-24 months

Based on UNICEF, and WHO recommendations, at 6-8 months of age children should be given in addition to breast milk, 2-3 table spoons (63mls) of complementary foods, at 9-11 months increasing to 3-4 times daily and given half a cup (125mls) and at 12-24 months they should be given three-quarter to a full cup (250mls) of complementary food per serving with additional nutritious snacks offered 1-2 times per day as desired (WHO, 2009).  According to FAO (2011), UNICEF (2010) and Brown (2003), children at 6-12 months should be given complementary food  2-3 times a day while those at 12-24months should be given 3-4 times a day due to their increased rate of growth as well as energy requirement as child grows.

Therefore, if the porridge formulated in this study will be fed to these children it is then assumed that children of 6-8 months will take (65*3) =195 mls per day, 9-11 months (125*3) =375mls per day while 12-24months will take (250*4) =1000mls per day. By considering the formulation (SAPO5) which was the most accepted by sensory evaluation panelists, the formulated porridge will provide 213.59 Kcal (31.5%) energy, 6.1g (66.6%) protein, 101.12µg (26.5%) vitamin A, 11.7mg (167%) iron and 1.17mg (39%) zinc for children aged 6-8 months; 409.91Kcal (49.4%), 11.7g (106%), 200.66 µg (66%), 22.5mg (321%) and 2.25 mg (75%) for 9-11 months; and 1,093.1Kcal (100%), 31g (238%), 535.1 µg (178%), 54 mg (711%) and 5.4 mg (180%) respectively for children aged 12-24months. Therefore, these results suggest that the formulated porridge can contribute more than the recommended allowances of some nutrients targeted in this study.

### 3.1.10 In *vitro* protein digestibility

*In vitro* protein digestibility (IVPD) has been reported to be nearer to true digestibility as it is usually used as a quicker and convenient alternative to know in vivo protein digestibility (Adam *et al.*, 2015). Despite the results revealing insignificant difference of in *vitro* protein digestibility between flour and porridge, flour had higher values than porridge. The slight decrease of in *vitro* protein digestibility observed in porridge samples could be attributed with cooking effect. The reduction of *in vitro* protein digestibility resulted from heat processing might be attributed to amino acid degradation, formation of intramolecular disulfide bonds and maillard reaction as changes associated with heat processing (Muyonga *et al.,* 2014). This observation is different from a study by Shimelis and Rakshit, (2007) who reported increased *in vitro* protein digestibility after cooking.

On the other hand, the observed values of in vitro protein digestibility in the current study were higher than those reported by Nkundabombi, *et al.* (2015); Anigo *et al.* (2010) and Ali *et al.* (2009). This indicates that when this product will be consumed, there will be more available protein for nourishing the body.The increased in vitro protein digestibility reported in this study could be attributed to processing methods like germination, roasting, sprouting and extrusion cooking  involved which may be not only due to removal or reduction of anti-nutrients, but also may be attributed to breakdown of the native protein structure, including enzyme inhibitors and lectins; differential solubility of oligosaccharides and their diffusion rates; and phytase activity to break down phytic acid in the seeds which then leads to an increased in *vitro* protein digestibility Shimelis and Rakshit 2007) and (Prakrati *et al.*,(1999).

### 3.1.11 Conclusion

Based on the targeted nutrients of interest in this study results showed that, Soybeans and amaranth grains contributed to high energy and protein densities, OFSP contributed to high beta-carotene density, while pumpkin seeds contributed to zinc and iron density. In vitro protein digestibility was higher in all formulations than in reference samples. This proves that, formulated flour had higher amount of targeted nutrients compared to the reference flours. Therefore, it can be concluded that, utilization of soybeans, amaranth grains, pumpkin seeds and orange fleshed sweet potato can help in improving energy, protein, vitamin A, iron and zinc contents of the complementary porridges used in Tanzania. In adopting these ingredients in complementary feeding, a great care should be taken on the implications of excess intake of proteins, vitamin A, iron and Zinc.

## 3.2 Sensory properties, consumer acceptability and shelf life stability of nutrient dense porridge made from locally available foods for infants in Tanzania


### Abstract

Complementary foods in most of developing countries including Tanzania are based on cereals, tubers and traditional foods like plantains, yams and cassava. Other nutrient dense foods that can be incorporated in complementary feeding are locally available but are underutilized due to un awareness among people on their nutritional contribution in complementary foods. Different approaches of utilizing the locally available nutrient dense foods are needed so as to offer communities' opportunities to feed their children nutrient dense foods based on locally available, low costs, easily adopted as well as of highly acceptable attributes foods. This study utilized soybeans, amaranth grains, pumpkin seeds and orange fleshed sweet potato to formulate nutrient dense porridge, assess its sensory properties, consumer acceptability and shelf stability. Seven porridge samples, five formulations (SAPO1-5) and two control groups (SOSP and SMGMP) were evaluated for their acceptability using seven point and nine point hedonic scales as well as for quantitative descriptive analysis using 1-10 scale. Although all porridge samples were found acceptable, SAPO5 was the most accepted. Attributes color hue, aroma, sweetness and oiliness were the key drivers to consumer liking of the product. All attributes scores for all formulations decreased with increased storage time. SAPO1 had shortest ( 22 and 23days) shelf life compared to SAPO5 ( 63 and 85days) for linear and Arrhenius equations respectively. It was concluded that SAPO5 could be recommended for the adoption of this product since its ingredients proportions provided the most accepted product and of the longer shelf life.



**Key words**: *shelf life, consumer acceptability, quantitative descriptive analysis*

### 3.2.1 Introduction

Soybean, amaranth grains, pumpkin seeds and orange fleshed sweet potato are foods which are locally produced in Tanzania for their different uses. These foods have been produced and utilized in different food products in the world due to their substantial contribution to the nutrient requirements (Okoth*et al,* 2016; Waized *et al*., 2015; Revathy and Sabitha 2013 and Laswai and Kulwa, 2010). These foods can be utilized in complementary feeding and provide a nutrient dense food with acceptable attributes. Notwithstanding their richness in different nutrients, these foods are not being well utilized in different recipes so as to contribute in combating the problem of malnutrition in children.

Soybean can supply protein as well as some micronutrient which has made it to be used in complementary feeding as it was reported in findings by Ojinnak *et al.,* (2013) Laswai and Kulwa, (2010); Anigo *et al.,* 2010 and Mosha *et al.(*2000). Most of homemade complementary foods in Tanzania lack adequate nutrients like energy, protein, vitamin A, zinc and iron which are essential for child growth and development. There are plenty of locally available nutrient dense foods such as pumpkin soybeans, orange fleshed sweet potato, pumpkin seeds and amaranth grains which can be incorporated in complementary foods and supply the food with acceptable sensory attributes as well as the required nutrients to children.

The utilization of orange fleshed sweet potato as a source of vitamin A and energy has been of great significance in Tanzania and other African countries (Waized *et al*., 2015). Its inclusion in complementary foods in Tanzania will help in improving energy content of homemade complementary foods as well as fighting against vitamin A deficiency. Pumpkin seeds are known for its medicinal and nutritive components as they contribute in minerals protein and fat in foods ( Revathy and Sabitha, 2013 and Hamed *et al*., 2008). The addition of pumpkin seeds in complementary feeding will help in supplying minerals in complementary foods as well as improving the protein, energy and vitamin status of foods. Together with these, amaranth grains will supply protein of high quality as well as vitamins and energy when incorporated in complementary foods (Okoth *et al.,* 2016 and Muyonga *et al.*,2014).

Sensory evaluation is a scientific method that suggests measures and interprets responses to food products through sight, touch, smell and taste (Learning and Choi, 2014). In this study, sensory properties of the formulated porridge will be affected by both ingredients and processing methods involved. Attribute aroma is mostly contributed by extrusion cooking and roasting method, sweetness is improved by inclusion of ingredients like orange fleshed sweet potato, oiliness by inclusion of soybeans, amaranth grains and pumpkin seeds while color/ hue is contributed by both roasting method and orange fleshed sweet potato as an ingredient. When all these attributes are improved, they will contribute in driving consumers towards liking and accepting the product. In order to know the consumer liking of the product in relation to its sensory attributes, the quantitative descriptive analysis the type of sensory evaluation should be conducted so as to know which attributes drove consumers in liking a particular product.

Based on their nutrients contribution in growth and development of children, this study aimed at utilizing these foods to develop a nutrient dense complementary porridge and assess its sensory properties through quantitative descriptive analysis and consumer acceptability through hedonic scale as well as studying its shelf life stability.

#### 3.2.1.2 Objectives

#### 3.2.1.3 Specific objectives

1. To assess sensory properties and consumer acceptability of the orange fleshed sweet potato-based complementary porridge.
2. To assess the shelf life stability of the formulated flours.

### 3.2.2 Materials and method

#### 3.2.2.1 Study area

This study was conducted at Sokoine University of Agriculture in Morogoro, Tanzania. Solar drying of crops and product development were carried out at Solar Tunda Project premises while sensory analyses activities were carried out at Department of Food Technology, Nutrition and Consumer sciences laboratory.

#### 3.2.2.2 Materials

Fresh orange fleshed sweet potatoes were purchased from farmers in Arusha, pumpkin seeds, Soy beans, amaranth grains, ingredients and materials were purchased from Morogoro market, Tanzania.

#### 3.2.2.3 Research designs

A complete Randomized Design (CRD) was carried out whereby different formulations were considered as the principal factor. The effect of principal factor on sensory properties and consumer's acceptability was determined.

#### 3.2.2.4 Formulations development

Fourteen formulations were developed using Nutrisurvey (2007) software. However, only five formulations with at least half of the targeted amount of the nutrients of interest in the study were taken (Table 1).

**Table 3.10 : Various formulations used in the study**

| | Soy bean (%) | Amaranth Grain (%) | Pumpkin seeds (%) | OFSP (%) | Energy (Kcal) | Protein (g) | Vitamin A (µg) | Iron (mg) | Zinc (mg) |
|---|---|---|---|---|---|---|---|---|---|
| **SAPO1** | 50 | 20 | 25 | 5 | 370.2 | 26.7 | 476.7 | 8.6 | 2.8 |
| **SAPO2** | 40 | 20 | 30 | 10 | 393.8 | 27.2 | 478.6 | 8.9 | 3.0 |
| **SAPO3** | 30 | 35 | 20 | 15 | 408.1 | 26.1 | 472.4 | 9.4 | 3.6 |
| **SAPO4** | 25 | 25 | 20 | 30 | 426.0 | 29.4 | 488.6 | 8.9 | 2.8 |
| **SAPO5** | 20 | 40 | 15 | 25 | 292.8 | 25.3 | 2120.5 | 6.6 | 3.0 |

SAPO1= 50%soybean, 20% amaranth grain, 25% pumpkin seeds 5% Orange Fleshed Sweet Potato SAPO2= 40%soybean, 20% amaranth grain, 30% pumpkin seeds 10% Orange Fleshed Sweet Potato SAPO3=30%soybean, 35% amaranth grain, 20% pumpkin seeds 15% Orange Fleshed Sweet Potato SAPO4=25%soybean, 25% amaranth grain, 20% pumpkin seeds 30% Orange Fleshed Sweet Potato SAPO5=20%soybean, 40% amaranth grain, 15% pumpkin seeds 25% Orange Fleshed Sweet Potato

#### 3.2.2.5 Porridge preparation

Seven different porridge samples, five from developed formulations and two control groups were prepared by mixing 300g of flour in 1500ml of boiling water. The mixtures were constantly stirred for about 15 minutes, and then 30g of sugar was added to the ready porridges.

### 3.2.3 Sensory evaluation

#### 3.2.3.1 Quantitative descriptive analysis (QDA)

Quantitative Descriptive Analysis is one of the useful and informative types of sensory evaluation test. It gives quantitative description of products based on sensory properties. QDA helps in providing the answers of what is the nature and magnitude of differences between tested samples. Together with consumer test data, QDA shows which attributes of the tested samples drove consumers towards liking of the particular sample. In this study, QDA test was conducted at Food technology laboratory using 20 trained judges. Judges were selected and trained according to ISO standard (1993) for four days, whereby they developed and agreed on six descriptors which were hue, aroma, sweetness, thickness, grittiness and oiliness (Table 2). They also developed and agreed on a ten point line scale (1= no or low intensity while 10 for high intensity) to quantify the magnitude of the sensory attributes. The samples to be tested were coded with 3-digits random number and served to each judge in small containers and were asked to rate the samples based on references agreed and by using the scale developed during training. All principles of good sensory practices such as coding, randomization and rinsing of the mouth were observed.

After four days of training, a pre- test study was carried out so as to test the effectiveness of the training before the actual test. The actual test was carried into two sessions whereby after one session judges were given a break of 30 minutes before the second session. The aim of these two sessions was to test the reproducibility of the judges as it is required in QDA study. For judges 6 out of 20 deviated very much from their first answers of the first session and were removed from the list while 14 who were able to reproduce high percent of their answers, their data were considered for analysis.

**Table 3.11 : Attributes, references and anchors developed in quantitative descriptive analysis panel training**

| Attribute | Definition | Reference | Anchors |
|---|---|---|---|
| **Color** | Color hue | Brownish; anything associated With brownish | Low to high |
| | Color intensity | Clear, strong color | Low to high |
| **Aroma** | Aromatic | Cooked aroma<br>Porridge aroma | |
| **Sweetness** | Sweetness intensity | The sweetness associated with sucrose solution | Not sweet to very sweet |
| **Thickness** | Porridge viscosity | The thickness associated with Honey viscosity | Not viscous to very viscous |
| **Grittiness** | Mouth feel of the porridge | Presence of chewable particles in The porridge | Low to high |
| | Particles present in the porridge | | |
| **Oiliness** | Presence of visible oil in the porridge | Oily feel in the mouth | Not oily to very oily |

### 3.2.3.2 Consumer acceptability of the porridge

In this study we used mothers (with children of 6-23 months) and students in assessing the acceptability of the formulated porridge from both groups. According to studies by Ruwaida *et al.,* (2016); Guilermo *et al.,* (2005) and Chamber and Wolf, (1996), a number of consumer size can vary depending on experimental design as well as economic situation. The accepted consumer size for acceptance / preference test is 50 and above. From this study, a panel of 76 people including mothers, and students were involved. Students were involved so as to provide more details about the sensory properties of the porridge while mothers and non- teaching staff were involved to simply say if their children could like the porridge. With mothers seven points hedonic scale where 1= dislike extremely through 4= neither like nor dislike and 7= like extremely was used according to their level of understanding, while with students a nine points hedonic scale with 1= dislike extremely through 5= neither like nor dislike to 9= like extremely was used because they could tell the differences even when wide scale was used. The samples were coded with 3 digits random number and served to each panelist. Water was given to every panelist so as to rinse their mouth so as to avoid taste interference

### 3.2.4 Storage stability studies

Shelf life of the formulated flours was assessed by analyzing the moisture content, free fatty acid, peroxide value and sensory properties at different storage conditions and times. The flour was packed in polythene bags and stored at room temperature and others in the oven at 45˚C and 35˚C as recommended for acceleration condition to be at least above ( > 15 ˚C) from room temperature so as to speed up the deterioration reaction. Two temperatures of 45˚C and 35˚C were used in case of weather condition fluctuation whereby the constant temperature was considered in deciding the acceleration condition. For these results 45˚C was selected. Samples were removed at intervals of one week during storage and analyzed for the mentioned parameters. For every week of storage, porridge was made from the stored flour and subjected to sensory analysis by another consumer panel consisting of 16 male and female university students (semi-trained) pursuing Bachelor of Science degree in Food science and technology. A nine points hedonic scale with values ranged from 1 (dislike extremely) through 5 (neither like nor dislike) to 9 (like extremely) was used. Samples were served to consumers at 70 $^0$C (for them to be able to tell the real thickness of the porridge) at around 10: 00am hour and panelists were asked to express their degree for liking sensory attributes which were appearance, viscosity, aroma, taste and general acceptability. All principles of good sensory practices were observed.

### 3.2.4.1 Determination of Peroxide Value (PV)

In determining peroxide value, 5g of the sample was warmed in water bath at $40^0C$ for 45 minutes. The sample was then mixed with 25ml of solvent mixture (Acetic acid: chloroform) and 1g of solid potassium iodide in a boiling test, and heated in a boiling water bath for 30 seconds. The heated content was then poured into 100ml conical flask and against standardized 0.002M sodium thiosulphate using starch solution as an indicator until blue black color disappeared. The Peroxide value was calculated using Equation (i)

$$\text{Peroxide value (meq/Kg)} = \frac{(A-B) \times N \times 1000}{\text{Weight of sample taken (g)}} \qquad \text{Equation (i)}$$

Where; A= Volume of $Na_2S_2O_3$ used for sample, B= Volume of $Na_2S_2O_3$ used for blank C= Normality of $Na_2S_2O_3$.

### 3.2.4.2 Acid value (AV) as free fatty acids (FFA)

Free fatty acid in the sample was determined by dissolving 5g of the water bath warmed sample at $40^0C$ for 45 minutes in 20ml of 5% diethyl ether in alcohol. The mixture was titrated against 0.1M sodium hydroxide using phenolphthalein indicator until pink color appeared. Equation (ii) was used for calculating the acid value.

$$\text{Acid value in mg NaOH/g} = \frac{(V1-V2) \times 0.004\text{g/ml} \times \text{Extraction vol. (ml)} \times 1000}{\text{Sample weight (g)}} \qquad \text{Equation (ii)}$$

### 3.2.4.3. Predictive models

The 10 Mill equivalent/kg (mEq/kg) was used as a limit for extruded products to solve equations (y=0.363x+0.02; y= 10mEq, x= days) that were given from peroxide value (at 45 $^0C$) against storage time graphs. Another graph was created (log ts versus 1/T (K)) (y=2276x-5.9506) whereby the "X" value from the equation was (28 + (273)) which was a room temperature in Kelvin and y was estimated days. These were the equations used to estimate shelf life (days) of the formulated four samples.

### 3.2.5 Statistical data analysis

Data were analyzed by using R software (R Core Team) for two way analysis of variance to determine the significant differences between samples at $p<0.05$. Means were separated by Tukeys Honest significant difference at $p<0.05$. Principal component analysis (PCA) was done by Panel Check software to assess systematic variations between variables.

### 3.2.6 Results

#### 3.2.6.1 Quantitative Descriptive Analysis

The mean intensity scores of samples differed significantly ($p<0.05$) with the developed formulations having higher values for aroma (5.4 to 5.6), Hue (5.1 to 7.0), sweetness (5.3 to 5.6) and oiliness (4.2 to 4.6) than references with respective values of (3.9 to 4.4 ), (4.4 to 4.6), (4.8 to 5.3) and (2.3 to 2.6). The variation between formulations was also significant. On the other hand, the references had significantly higher thickness score of (8.1) and grittiness of (6.2) than formulated samples (SAPOs) with lower values of (4.5 to 5.3) and (3.1 to 4.4) respectively as shown in Table 3.12.

**Table 3.12 : Mean intensity scores of porridge samples by sensory panel**

| Sample | Aroma | Hue (brownish) | Thickness | Grittiness | Sweetness | Oiliness |
|---|---|---|---|---|---|---|
| SAPO1 | $5.4\pm 1.67^{a}$ | $5.6 \pm1.45^{b}$ | $4.8\pm1.41^{bc}$ | $4.4\pm1.31^{c}$ | $5.3\pm1.75^{ab}$ | $4.2\pm1.98^{a}$ |
| SAPO2 | $5.6 \pm 1.47^{a}$ | $5.1 \pm1.46^{bc}$ | $4.5\pm1.35^{b}$ | $3.3\pm0.90^{d}$ | $5.5\pm1.75^{ab}$ | $4.6\pm1.98^{a}$ |
| SAPO3 | $5.6\pm1.67^{a}$ | $7.0 \pm1.44^{a}$ | $5.3\pm1.44^{b}$ | $3.5\pm1.23^{d}$ | $5.6\pm1.63^{a}$ | $4.3\pm1.92^{a}$ |
| SAPO4 | $5.5 \pm1.20^{a}$ | $6.9\pm1.76^{a}$ | $5.0\pm1.55^{bc}$ | $3.1\pm1.33^{d}$ | $5.6\pm1.52^{a}$ | $4.2\pm1.89^{a}$ |
| SAPO5 | $5.6\pm1.23^{a}$ | $6.9\pm1.086^{a}$ | $5.3\pm1.46^{b}$ | $3.7\pm1.46^{cd}$ | $5.5\pm1.29^{ab}$ | $4.2\pm1.85^{a}$ |
| SOS | $4.4 \pm 1.49^{b}$ | $4.4 \pm0.95^{c}$ | $8.4\pm0.83^{a}$ | $6.9\pm1.33^{a}$ | $5.3\pm1.68^{ab}$ | $2.6\pm1.25^{b}$ |
| SMGM | $3.9\pm1.53^{b}$ | $4.6\pm1.6^{c}$ | $8.2\pm0.83^{a}$ | $5.6\pm1.23^{b}$ | $4.8\pm1.92^{b}$ | $2.3\pm1.25^{b}$ |

**Means bearing different superscript on the same column are significant different (P<0.05). Samples SAPOP1-SAPOP5 are complementary porridges made from formulated flours while SOSP and SMGMP are references (N=14).**

The bi-plot of principal component analysis shows that, PC 1 accounts for 87.2% of the variation and it was a distinction between SAPOs and control samples (SOS and SMGM) while PC 2 accounts for 10% of the variations and it was a contrast between SAPO 1 an 2 on one side and the rest of the samples. SAPO 1 and 2 were closely associated with aroma and oiliness attributes while SAPO 3, 4 and 5 were closely associated with hue and sweetness. Reference samples were associated with thickness and grittiness (Figure 7).

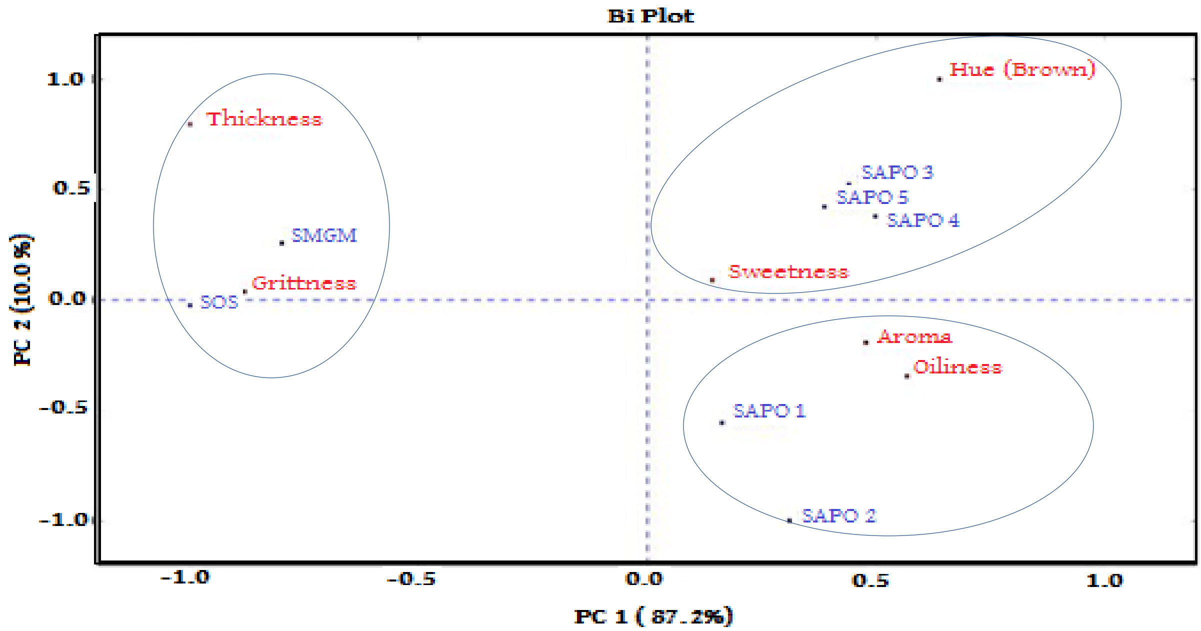
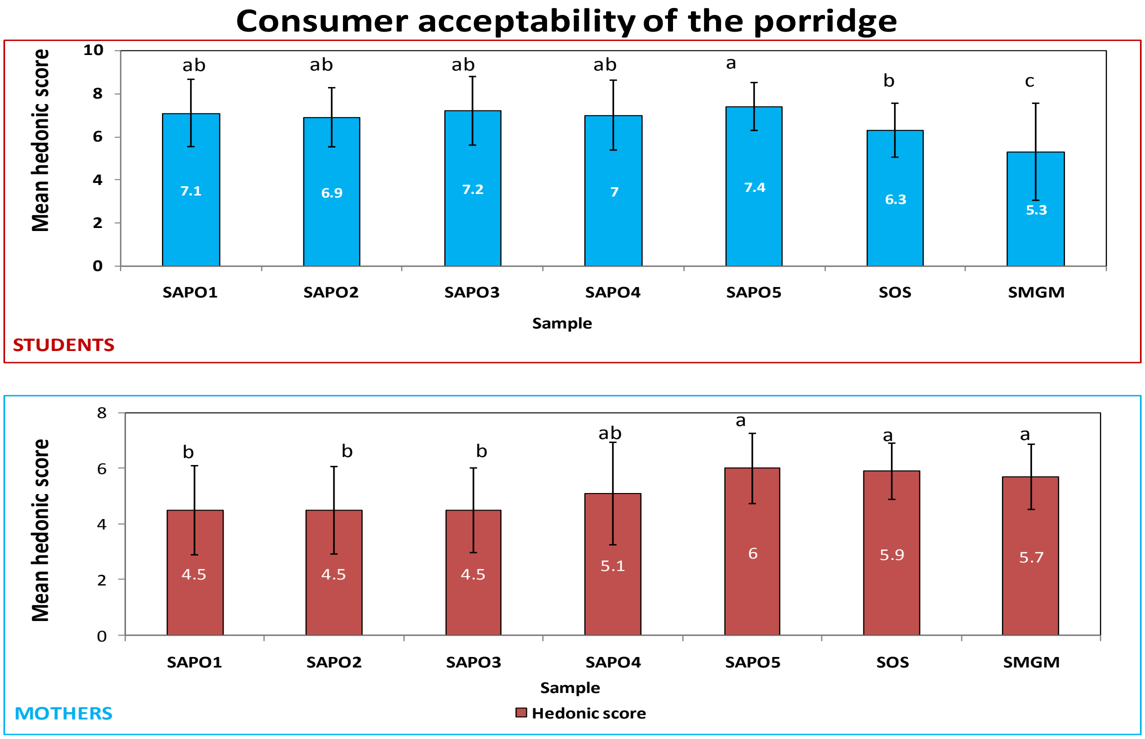



**Figure 7: Bi-plot of PCA showing association between samples and attributes**

### 3.2.6.2 Consumer acceptability

There was a significant ($p<0.05$) difference in acceptability of the porridge. Acceptability scores of the porridge for mothers ranged from 4.5 to 6.0 while with students ranged between 5.3 to 7.4 as shown in (figure 7). Mothers showed a significant ($p<0.05$) difference in acceptability between SAPO 1, 2 and 3 on one side and the rest of the samples on the other sides with the latter having higher values of 5.1, 6.0, 5.9, and 5.7 than the former with values of 4.5, 4.5,and 4.5. Contrary, the students showed a variation between samples with all SAPOs having higher hedonic values of 7.1, 6.9, 7.2, 7.0, and 7.4 than reference samples with value of 6.3 and 5.3 as shown in figure 8.

**Figure 8: Mean hedonic score for porridge samples by mothers and students**




**Samples SAPOP1-SAPOP5 are complementary porridges made from formulated flour while SOS and SMGM are references. SOS=Sorghum, Orange fleshed sweet potato and soybean. SMGM= Soybean, maize, groundnuts and millet. 1= like extremely, 2=like very much, 3 =like moderately, 4=like slightly 5= neither like nor dislike, 6= dislike slightly, 7= dislike moderately, 8= dislike very much 9= dislike extremely**

### 3.2.6.3 Relationship between descriptive data and hedonic liking by PLSR (Preference mapping)

Figure 9 shows the results from a PLSR using descriptive data as X-variables and liking rated by the consumers as *Y*-variables. It shows that majority of consumers fell to the left of the vertical Y-axis which showed the direction of liking with all formulated samples implying that that they were all liked by consumers. Furthermore, the formulated samples were positively correlated with hue, aroma, sweetness and oiliness attributes.

**Figure 9: shows the direction of liking of the product by consumers.**

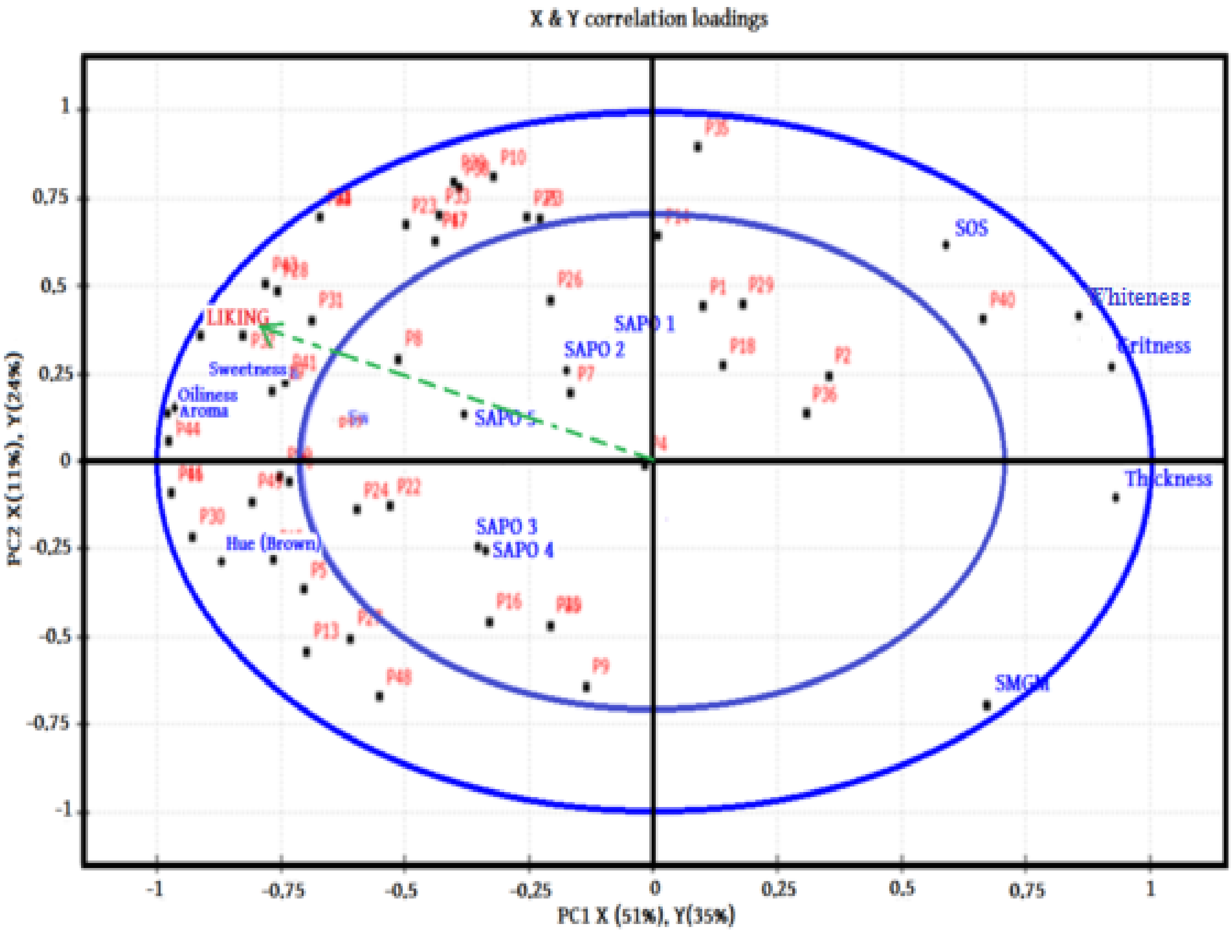



**Figure 9: Correlation loading from partial least squares regression of formulated porridge samples with descriptive data as X- variables and hedonic rating as Y- variables**

### 3.2.7 Shelf life stability study

#### 3.2.7.1 Predictive models

Table 3.13 shows the predicted shelf life of the formulated flour using Arrhenius equations. The model showed that shelf life of the formulated flour ranged from 23 to 85 days. The findings suggest that the storage stability decreased with increase in soybean and pumpkin seeds ratio.

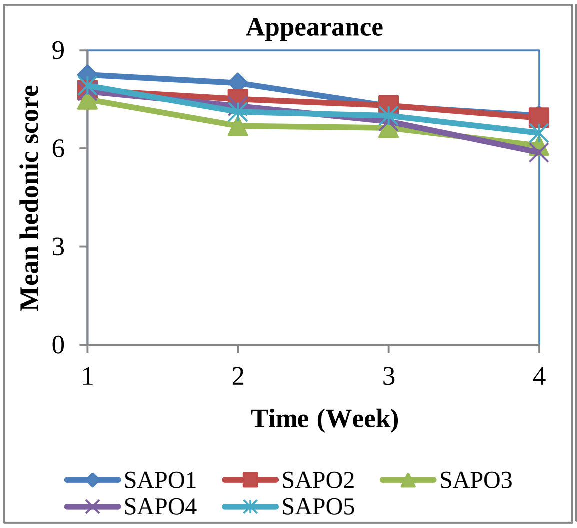
Table 3.13 : Arrhenius shelf life equation, $R^2$ and the estimated shelf life days at $25^0C$

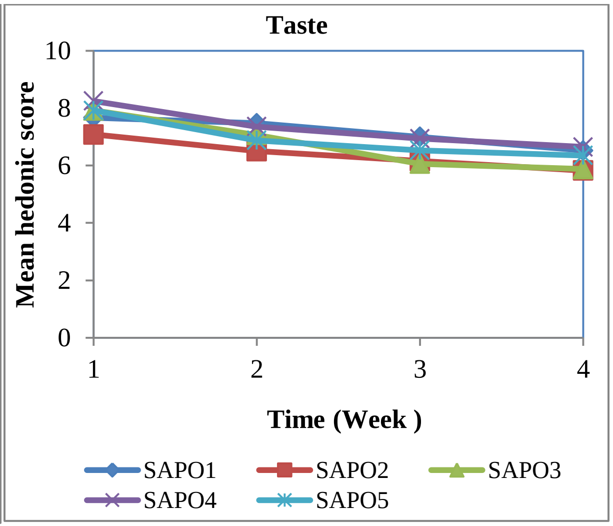
| Sample | Arrhenius equation | $R^2$ | Estimated shelf life (days) |
|---|---|---|---|
| SAPOF1 | Y= -357.84x +2.5646 | 1 | 23 |
| SAPOF2 | Y= -325.79x +2.544 | 1 | 28 |
| SAPOF3 | Y= 1704.8x - 4.0955 | 1 | 42 |
| SAPOF4 | Y= 2863.6x – 7.7878 | 1 | 66 |
| SAPOF5 | Y= 3752x – 10.66 | 1 | 85 |

### 3.2.7.2 Sensory properties

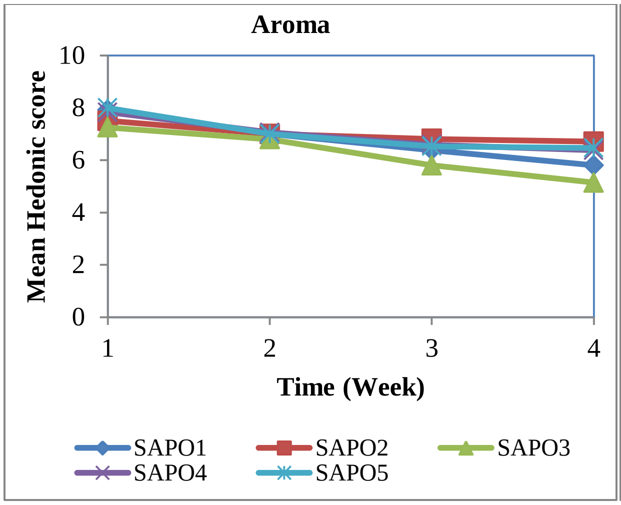
Figures 9 (a-e) shows the changes in sensory attributes of the flour which was stores for four weeks at a temperature of $45^0C$. All sensory properties in all samples tested decreased with increased in storage time implying that storage time had respective higher reduction in aroma, texture, taste and acceptability

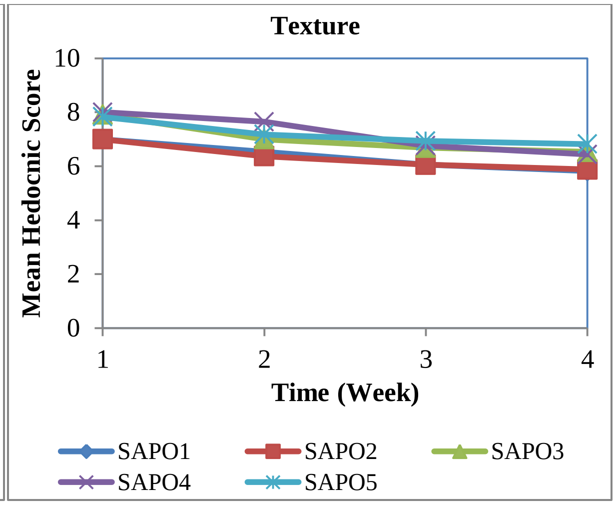
**Figure 10: (a-e) Changes of sensory attributes of the formulated flours during storage period**



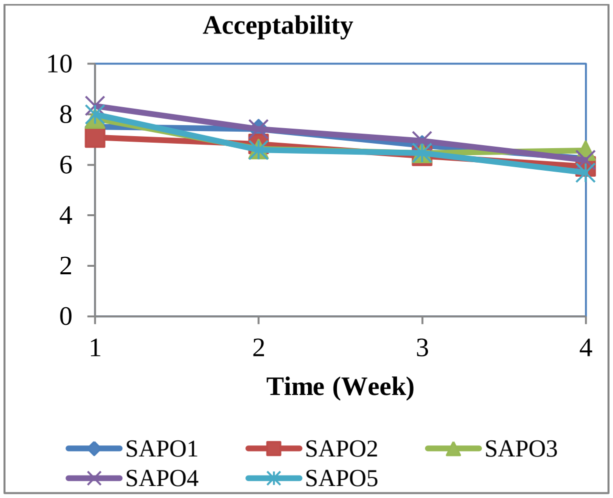




**(a)** **(b)**




**(c)** **(d)**

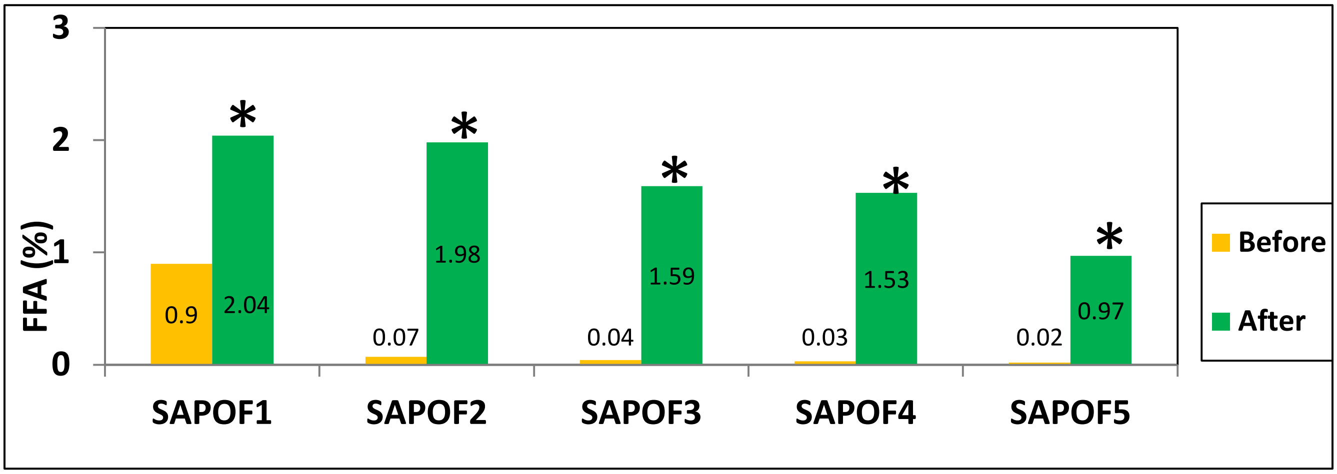



**(e)**

### 3.2.7.3. Free fatty acids

Changes of free fatty acid values of the flour before and after the four weeks of the storage are shown in figure 10. These results revealed that there was a significant difference in free fatty acids in the samples before storage and after storage. Free fatty acid values significantly increased in all samples during storage.

**Figure 11: Free fatty acids of the stored flour samples (4 weeks)**




### 3.2.8 Discussion

#### 3.2.8.1. Sensory properties

The results revealed that SAPO5 was the most accepted by all panelists. The findings showed that acceptability increased with decrease in soybean. This observation could be associated to the effect of beany flavor which has been reported to cause low acceptance of soybean based food products (Laswai *et al.,* 2010). Acceptability was on the other hand affected positively by amaranth grains ratio as it is shown in (Table 3). The increased ratio of amaranth grains increased the acceptability as it was observed in SAPO5 which had the highest amaranth grains ratio and it was the most accepted by both groups. This observation is in line with the findings by Oladimeji (2015); Muyonga *et al*. (2014) and Chauhan and Singh (2013) which showed the higher acceptability of the amaranth grain based food.

#### 3.2.8.2. Aroma

Aroma is an integral part of taste and general acceptability of the food before it is put in the mouth. It is an important parameter when tasting the sensory attributes of the formulated foods. The variation observed in aroma could be associated by effect of extrusion cooking and roasting of soybean and pumpkin seeds. As one of its advantages, extrusion cooking method improves the aroma of the product (Navale *et al.,* 2015). Therefore the higher mean scores for aroma in formulated samples compared to references were contributed by extrusion cooking involved.

This observation is similar to the findings reported by Leszek Moscicki (2011) and Ramachandra and Thejaswini (2015) that showed the effect of extrusion cooking on improving the aroma of the extruded product.

#### 3.2.8.3. Color hue

Color hue is an important attribute in food choice as well as acceptability. The variation observed in hue between formulations and reference samples could be associated with the ingredients used as well as the effect of roasting and extrusion cooking. Inclusion of orange fleshed sweet potato in the formulated samples together with extrusion and roasting of the ingredients used increased the brownish of the formulations. The effect of roasting and extrusion in this study corresponded with the findings by Navale *et al. (*2015); Riaz *et al.* (2007) and Guy (2001) that showed the impact on color of the roasted and extruded products.

#### 3.2.8.4. Thickness

Thickness is a very important to be considered in complementary porridge because it helps to determine amount of energy taken. The observed variation in thickness between formulations and control groups could be attributed to the ingredients used. The higher values observed in control groups is associated with the use of cereals. This is because the use of sorghum, maize, millet and other cereals is associated with bulkiness which leads to high thickness as it is also observed by Muhimbula and Zacharia (2010).

#### 3.2.8.5. Sweetness

No significant ($p>0.05$) difference in sweetness observed between samples. Nevertheless, formulations had higher mean scores of sweetness than control groups which could be due to the inclusion of orange fleshed sweet potato. Moreover, significant ($P<0.05$) difference in oiliness between formulations and control groups were connected to the inclusion of soybean, amaranth grains and pumpkin seeds. This observation is similar to findings by Ngozi *et al.*, (2014); Muyonga *et al.*, (2014) and Hassan *et al.* (2008) that show the contribution of fats from soybean, amaranth grains and pumpkin seeds when included in complementary foods.

### 3.2.9. Relationship between descriptive data and hedonic liking by partial least square regression

#### 3.2.9.1. Principle component of descriptive analysis of sensory data

The observed positions of samples in Bi- plot of principle component analysis were determined by a relationship between samples and attributes. The observed similarity of all formulations in hue, sweetness, aroma and oiliness compared to reference samples as shown by bi-plot of principal component analysis may be attributed to ingredients used as well as extrusion cooking effect. Furthermore, the high association of SAPO1 and SAPO2 and aroma and oiliness attributes could be due to higher ratio of soybean compared to other formulations while the positive correlation between SAPO3,4 and 5 and sweetness and color hue attributes could be due to the increased ratio of orange fleshed sweet potato as it is characterized by sweetness and orange color Table 3.2.

From the preference mapping, color hue, aroma, sweetness and oiliness observed to be the key attributes that drove the preference of consumers towards the tested samples. Color and appearance are the preliminary attributes that attract consumers to a food product and hence considered as guide for a good quality of foods associated with acceptability (Singh, 2014).

### 3.2.10. Shelf life stability study

This observed decrease of shelf life in SAPO1 and SAPO2 can be related to the high amount of fats in soybean and pumpkin seeds which then undergoes lipid oxidation in the short period of storage. The observed results are similar to the one reported by Revathy and Sabitha, (2013) and Granato *et al.*(2010) who reported shorter shelf life stability of pumpkin seeds and soybean flour. Therefore, this suggests that the longer shelf life in SAPOF5 than SAPOF1 could be due to due to the decreased amount of soybean and pumpkin seeds ratio Table 3.2

Results from figure 9 (a-e) revealed that, all attributes tested, which were appearance, taste, aroma, texture and acceptability scored lower with increased time of storage. In order to be considered acceptable, the food product must attain scores above or equal to 5.0 (liked slightly) when a seven – point hedonic scale is used and 6.0 (liked slightly) when a nine–point hedonic scale is used. Therefore despite the reduction in sensory attribute scores after four weeks of storage, as presented in Figures 9 (a-e) all attributes tested were within the acceptable ranges as they scored 6.0 and above with exception of aroma only. The aroma attribute scored slightly lower compared to the other attributes. This could be associated to effect of oxidation of lipids which frequently affects aroma and flavor of the product.

The observed increased in free fatty acid values was associated with indicative hydrolysis of lipids during storage. Free fatty acids (FFA) are the products resulting from the hydrolysis of free fatty esters. Their presence is associated with hydrolytic rancidity in food products which may affect the flavor of the product (Evelyn, 2014 and O `Brien, 2008). The observed increase in FFA in (Figure 10) revealed that higher storage temperature ($45^0$C) catalyzed the hydrolysis reaction which resulted to higher amount of free fatty acids. This observation was similar to that reported by Akusu and Kibari, (2013) on the effect of storage period on the chemical stability and sensory properties of the food product. Egan *et al.* (1981) reported that acidity and rancid taste often begins to be noticeable in foods when free fatty acid content is about 1.5%. Since the free fatty acid content increased from 0.03 at week 0 to 2.04% at the fourth week, indicates that the values of free fatty acid were above the unacceptable limits. Therefore this suggested that the formulation attained the free fatty acid value of 2.04% could not be safe for use beyond the four weeks of storage

### 3.3. Conclusion

Based on the findings, there was a variation in sensory attributes between formulations and references and within formulations. Roasting method contributed to higher scores in aroma and hue than other formulated porridges, Orange fleshed sweet potato contributed to sweetness while soybeans contributed to higher scores of oiliness in all formulations compared to reference samples.

A formulation with lower ration of soybean but with higher ration of amaranth grains was the most accepted, and hence it can be recommended for adoption consumption of this product. Shelf life estimation of the stored flours based on sensory analysis revealed that all sensory attributes tested except aroma for SAPO3 remained within the acceptable limits (above 6 points) during four weeks of storage. The regression equations using linear and Arrhenius equations predicted that, formulation with higher soybean ration had shortest shelf life of 22 and 23 days respectively while the one with lower ration was predicted to have a longest shelf life of 63 and 85 days respectively.

### 3.4 General conclusion

It can be concluded that, we can formulate a nutrient dense product from locally available foods which can meet half/ more of the nutrient requirements of children aged 6-24 months. Based on the nutrients of interest in this study, all ingredients used had a cooperative contribution in improving the nutritional quality and sensory properties of the formulated product. Soybeans and amaranth grains contributed to energy and protein densities of the formulations, pumpkin seed had a great contribution on the iron, Zinc and some protein and vitamins in formulations while orange fleshed sweet potato contributed to vitamin A (beta carotene). The formulation which was the most accepted and with a longest shelf life was able to contribute up to recommended amounts of nutrients and even more than recommended daily allowances for some nutrients to the requirements of children 6-24 months. Therefore its adoption for complementary feeding is of great importance since it seems to be good enough to help in reducing malnutrition contributed by nutritionally poor quality complementary foods. In adopting this formulation, a great care should be taken on the implications of excess intake of proteins, vitamin A, iron and Zinc which are associated with health dangers to infants like chances of diabetes, obesity, kidney failure injury to internal organs and even death. Despite the contribution of energy and protein from soybeans, it also decreased the acceptability of the product due to its beany- flavor.

### 3.5 General recommendation

Since results from this study have revealed the significant contribution of the developed product to the nutrient requirements of children aged 6-24 month, it is therefore recommended that utilization of soybeans, amaranth grains, pumpkin seeds and orange fleshed sweet potato in complementary feeding should be promoted to our communities. Also, as one of the strategies of improving the energy, protein, vitamin A, iron and zinc in complementary foods used in Tanzania education on the nutrition benefits of these foods in complementary feeding should be provided to all caregivers.

*In vivo* mineral bioavailability study should carried out based on the formulation so as to know the percentage of the available minerals and other nutrients that will be absorbed directly to child`s Gastrointestinal. This will decide whether the formulation needs re- adjustment on ingredients ratio before it is recommended for infants and young children.

**Reference**


Adinsi, L., Akisso, H., Vieira G., Anihouvi, B., Fliedel, G., and Hounhouigan, J. (2014). Sensory evaluation and consumer acceptability of a beverage made from malted and fermented cereal; c se of gowe from benin. *Food Science and Nutrition,* 3(1): 1-9.

Akusu, M., and Kiin-Kabari DB.(2013). Effect of storage period on selected functional, chemical stability and sensory properties of bush mango (*irvingia Gabonensis*) seed flour. *Africa Journal of Food Science and Technology*. 4(6): 136-140

Ali, H., Haque, M. M., Chowdhury, M. M. R., & Shariful, M. I. (2009). In vitro protein digestibility of different feed ingredients in Thai koi ( Anabas testudineus ), *7*(1): 205–210.

Anigo, K. M., Ameh, D. A., Ibrahim, S., & Danbauchi, S. S. (2010). Nutrient composition of complementary food gruels formulated from malted cereals , soybeans and groundnut for use in North-western Nigeria, *4*: 65–72.

AOAC (1990). Official Methods of Analysis, 15th edition, Washington DC: Association of Official Analytical Chemists.

Atuonwu, a. C., & Akobundu, E. N. T. (2010). Nutritional and sensory quality of cookies supplemented with defatted pumpkin (Cucurbita pepo) seed flour. *Pakistan Journal of Nutrition*, *9*(7): 672–677. http://doi.org/10.3923/pjn.2010.672.677

Bentley M, Stallings R, Fukumoto M, Elder J. (1991).Maternal feeding behavior and child acceptanceof food during diarrhea episodes, convalescence,and health in the Central Northern Sierra of Peru. *AM J. Pub Health*, 83: 1-5.

Black, R. E., C. G. Victora, S. P. Walker, Z. A. Bhutta, P. Christian, M. de Onis, M. Ezzati, S. Grantham-McGregor, J. Katz, R. Martorell, and R. Uauy. (2013). "Maternal and Child Undernutrition and Overweight in Low-Income and Middle-Income Countries." Lancet 382 (9890): 427–451.

Blessing J. Akombi , Kingsley E. Agho, Dafna Merom, Andre M. Renzaho, John J. Hall. (2016). Child malnutrition in sub-Saharan Africa: A meta-analysis of demographic and health surveys (2006-2016) https://doi.org/10.1371/journal.pone.0177338. Published: May 11, 2017

Brown, A. (2008). Understanding food: Principles and preparation, 3rd edition. Belmont, CA: Thompson-Wadsworth.

Brown, K. G. D. and K. (2003). Update on technical issues concerning complementary feeding of young children in developing countries and implications for intervention programs. *Food and Nutrition Bulletin*, *24*(1): 5.

C, N. O. I., N, N. N., Ngozi, I., and N, M. A. (2014). Development and nutritional evaluation of infant complementary food from maize ( Zea mays ), soybean ( Glycine max ) and Moringa oleifera leaves, *3*(4): 290–299. http://doi.org/10.11648/j.ijnfs.20140304.19

Campbell M., Gold. (2009).The amazing pumpkin seed Compiled by CMG Archives http://campbellmgold.com accessed May 2016.

Cascio J. (2010). Pumpkin seeds. University of Alaska Fairbanks Cooperative Extension Services in Cooperation with the United States Department of Agriculture. www.uaf.edu/ces

Caulfield, L. E., Onis, M. De, Blössner, M., & Black, R. E. (2004). Undernutrition as an underlying cause of child deaths associated with diarrhea , pneumonia , malaria , and measles 1 – 3, 193–198.

Chauhan, A , and Singh, S. (2013). Influence of Germination on Physico – chemical Properties of Amaranth (Amaranthus Spp.) Flour. *International Journal of Agriculture and Food Science Technology*, *4*(3): 215-220.

Christides, T., Amagloh, F., & Coad, J. (2015). Iron Bioavailability and Provitamin A from Sweet Potato- and Cereal-Based Complementary Foods. *Foods*, *4*(3), 463–476. http://doi.org/10.3390/foods4030463

Cohen, E. and Saguy, I. (1985).Statistical evaluation of Arrhenius model and its applicability in prediction in food quality losses.*Journal of Food Processing and Preservation*, 9: 270-273

Corradin, G. and Peleg, M. (2007).Shelf life estimation from accelerated storage data.*Trends in Food Science and Technology*, 18: 37-49.

Creed de Kanashiro H, Penny M, Robert R, Narro R, Caulfield L, Black R.(2001). **I**mproving infant nutrition through an educational intervention in the health services and the community. Presentation at the WHO Global Consultation on Complementary Feeding, Geneva.

Dewey KG, Brown K. (2003). Update on Technical Issues Concerning Complementary Feeding of Young Children in Developing Countries and Implications for Intervention Programs. *Food Nutr. Bull.,* 24: 5-28.

Dewey, K. (2001). Nutrition, Growth and complementary feeding of the breastfed infant. *Pediatr. Clin. North America*, 48: 87-104

Dixit, A. K., Antony, J. I. X., Sharma, N. K., & Tiwari, R. K. (2011). 12 . Soybean constituents and their functional benefits, *661*(2): 367–383.

Duffy V, Bartoshuk L. (2000). Food acceptance and genetic variation in taste *.J.Am Dietassoc.100: 647-655.*

Echessa, A. C. P., Nyambaka, H., Ondigi, N., Omuterema, S., and Toili, W. (2013). Variation of Micronutrients in Pumpkin Fruit Varieties Grown Within the Lake Victoria Basin. *Food Science and Quality Management*, *17*(10): 71–81.

Egan, H., Kirk, S., Sawyer, R. (1981). Pearson`s Chemical Analysis of Foods, 8$^{th}$edn London: Churchill living stone

El Hassan, N. M., Hamed, S. Y., Hassan, A. B., Eltayeb, M. M., & Babiker, E. E. (2008). Nutritional evaluation and physiochemical properties of boiled and fried tree locust. *Pakistan Journal of Nutrition*, *7*(2): 325–329. http://doi.org/10.3923/pjn.2008.325.329

El-Adawy, T.A. and K.M. Taha. (2001). Characteristics and composition of different seed oils and flour *Food Chem* 74: 275-284

Emire, S.A, & Arega, M. (2012). Value added product development and quality characterization

Evelyn, O. (2014). Final report on accelerated shelf life eveluation of instant noodles made with fortfied flour. *Food Innovation and Resource Centre*, 58 (5): 10-34

Ezzati M. Lopez D. Rodgers A,.(2002). Selected major risk factors and global and regional burden of disease.Comparative Risk Assessment Collaborating Group.Lancet ;360:1347-60. [PubMed]

Fao. (2011). Complementary Feeding for Children Aged 6-23 months, 1–41. Retrieved from http://www.fao.org/docrep/014/am866e/am866e00.PDF

Fellows P. (2000).Food processing Technology. *Principles and practices*. Woodhead Publishing Limited. Pg 295-306.

Food and Agriculture Organization of the United Nations (FAO). (2004). FAO Statistics. Retrieved from http://www.apps.fao.org

Forouzanfar, M. H., L. Alexander, H. R. Anderson, V. F. Bachman, S. Biryukov, M. Brauer, R. Burnett, D. Casey, M. M. Coates, A. Cohen, and K. Delwiche. (2015). "Global, Regional, and National Comparative Risk Assessment of 79 Behavioural, Environmental and Occupational and Metabolic Risks or Clusters of Risks in 188 Countries, 1990–2013: A Systematic Analysis for the Global Burden of Disease Study. Lancet 386 (10010): 2287–2323.

GibsonS,Ferguson E, Lehrfeld J (2010). Complementary foods for infant feeding in developing countries: their nutrient adequacy and improvement. *Eur. J. Clin. Nutr*., 52: 764–770.

Glaml, S.Y., Achlnewhu and Ibaakee C. (2005). The quality and sensory attributes of cookies supplemented with fluted pumpkin seed flour. *Journal of Food Science Tecnology.*, 40: 613-620

Global Nutrition Cluster. 2016. Who We Are. Accessed, July,2017 http://nutritioncluster.net/gnc/partners/.

Granato, D., Masson, M. L., João, R., & Freitas, S. De. (2010). Stability studies and shelf life estimation of a soy-based dessert, *2009*(003893), 797–807.

Gulla, S. and Waghray, K. (2012).Blending of oils: A case study on storage stability and sensory characteristics of a ready to eat extruded snack. Journal of Nutrition, Dietetics and Food Science, 2(1): 1-14

Guillermo Hough, Ian Wakeling, Andrew Mucci, Edger Chamber, Ivan Mendez and Leonardo Rangel Alves. (2005). Number of consumers necessary for sensory acceptability test. *Food Quality and Preference, 17 (2006): 522-26.*

Guy, R. (2001). Extrusion cooking. Technologies and applications. International Journal of Innovative, Science, Engineering and Technology, 2(4): 1- 12.

Hagenimana, A., Ding, X., and Fang T. (2006). Evaluation of rice flour modified by extrusion cooking. *Journal of cereal Science,* 43: 38-46.

Hamed, S. Y., Hassan, N. M. El, Hassan, A. B., Eltayeb, M. M., & Babiker, E. E. (2008). Nutritional Evaluation and Physiochemical Properties of Processed Pumpkin ( Telfairia occidentalis Hook ) Seed Flour, *7*(2): 330–334.

Hellen Keller International. (2012). Orange fleshed sweet potato: Situation Analysis and Needs Assessment. Tanzania report, Hellen Keller International: Dar Es salaam.

Hurrell R. (2003). Influence of Vegetable Protein Sources on Trace Element and Mineral Bioavailability. *J. Nutr.*, 133: 2973S-2977S

Institute of Food Science and Technology. (1993). *Shelf life of foods- Guidelines for its determination and prediction*, London, Institute of Food Science and Technology

International Potato Centre (CIP). (2010). Orange-fleshed Sweet Potato for Africa Catalogue Lima, Peru: *International Potato Centre*. Retrieved from http://cipotato.org/publications/pdf/005374.pdf

Ishaq, N. and Ehirim, B. (2014) Improving soybean productivity using biotechnology approach in Nigeria. *World Journal of Agricultural Sciences 2 (2): 013-018*

Jana, R. A. (1982). Status of Sweet Potato Cultivation in East Africa and Its Future.In R.L. Villarreal & Griggs, T.D. (Eds.).*Proceedings of International symposium on Sweet Potato* (63-76). Taiwan, China: Asian Vegetable Research and Development Center.

Jaya S. and Das, H. (2005*).*Accelerated storage, shelf life and color of mango powder.*Journal of Food Processing and Preservation, 29: 45-62.*

Kathyrn dewey. (2001). guiding principles for complementary feeding of the breastfed. Pan american Health Organisation. *Journal of Clinical Nutritionournal of Clinical Nutrition*, 3: 18–25.

Kaur A., Singh N., Ezekiel R. and Guraya H.S. (2007). Physicochemical, thermal and pasting properties of starches separated from different potato cultivars grown at different locations, *Food chemistry*, 101: 643-651.

Kavishe P. (2003).Nutritio: Relevant Actions in Tanzania. *Tanzania Food and Nutrition Centre, Monograph Series No.1 pp 20; Tanzania*. Tanzania Food and Nutrition Centre, Dar Es Salaam.

Kilcast D. and Persis S. (2003). The stability and shelf life of food. Food processing technology-Principle and practices, second edn.(ISBN: 185573 533 4).

Labuza T. and Riboh D. (1982).Theory and application of Arrhenius kinetics to the prediction of nutrients losses in foods .*Journal of Food Technology,* 36: 66-74.

Labuza, T, and Kamman J.F. (1983). Reaction Kinetics and Accelerated test stimulation as function of Temperature. (Eds); Saguy, I., Marcel D. Inc., New York, pp: 71-115.

Labuza, T. (1982).Scientific evaluation of shelf life. In shelf life dating of foods: food and Nutrition press: Wastport, 41-87.

Lalude, L., Fashakin, B. (2006). Development and nutritional assessment of a weaning food from sorghum and oilseeds. *Pakistan J Nutr 5 (3):* 257-260.

Laswai, H.,Martin H., Kulwa K. (2010). Nutrient content and acceptability of soybean based complementary food. *African Journal of Food Agriculture, Nutrition and Development 10(1): 2040–2049.*

Lawless, T., Heyman H. (2010) Sensory evaluation of food. Principles and practice, 2nd edition New York: Springer : 563, 565, 566.

Learning, B. and Choi, S. E. (2014). Chapter 3 Sensory evaluation. *Food Science: An Ecological Approach*, 84–111.

Lutter, C. (2013). Opinion : Resp onse to " Adequate Nutr ient Intakes for Infancy , Part 2 : Complementary Food fr om 6 to 24 Months ." *Sight and Life*, *27*, 42–43. Retrieved from http://www.sightandlife.org/fileadmin/data/Magazine/2013/27_1_2013/Adequate_nutrient_intakes_for_infancy_opinion.pdf

Magala-nyago, M., Kikafunda K., Mwasaru, M., Connelly, K. (2005). Evaluation nutritional value of malted and extruded finger millet based complementary foods. African crop science conference proceedings 7: 677-686.

Malema.B.,Laswai H., Myaka F., and Kirenga G. (2005).S oybean production and utilization in Tanzania. Ministry of Agriculture Food Security and Cooperatives Crop development division, crop promotion services (CPS), Dar Es Salaam, Tanzania.

Mamiro P., Kolsteren P, Roberfroid D, Tatala S, OpsomerS., Van Camp H. (2005). Feeding Practices and Factors Contributing to Wasting, Stunting, and Iron-deficiency Anaemia among 3-23-months.

Maria, L., Carvalho, J. De, Barros, P., Luiz, R., Godoy, D. O., Pacheco, S., … Ramos, R. (2012). Total carotenoid content , α -carotene and β -carotene , of landrace pumpkins ( Cucurbita moschata Duch ): A preliminary study. *FRIN*, *47*(2): 337–340.

Martins, R. and Silva, C. M. (2004). Computational design of accelerated life testing applied to frozen beans. *Journal of Food Engineering,* 64: 455-464

Mcginn, C.P. (1985). Evaluation of shelf life.*IFST proceedings*, 15 (3) (Part 2), 153-161. London: IFST.

Meenakshi, J., Benerji, A., Manyong, V., Tomlins, K., Hamukwala, P., Zulu R. and Mungoma C. (2010). Consumer acceptance of pro vitamin A orange maize in rural Zambia: HarvestPlus Working Paper No. 4.

Meilgaard, MC.,Civille, V., Carr T.(2007). *Sensory evaluation techniques*, 4th edition Boca Raton.CRC press.

Michaelsen, K. andFriis, H. (1998). Complementary Feeding: A Global Perspective. *Nutr.*, 14: 763-766

Ministry of health and social welfare.(2013). Infant and Young Child Feeding National Guidelines.The United Republic of Tanzania.

Mizrah S., Labuza T. and Karel M. (1978). Feasibility of accelerated tests for browning in dehydrated cabbage. *Journal of Food Science 35: 804-807.*

Moscicki, L, Mitrus, M, Wojtowicz, A, Oniszczuk, T, & Rejak, A. (2013). Extrusion-Cooking of Starch: *Advances in Agrophysical Research* 29: 319-346.

Moscicki, L., Mitrus, M., Wojtowicz, A., Oniszczuk, T. and Rejak, A. (2011). Extrusion-Cooking of Starch. *Journal of Food Engineering, 31: 277-296.*

Mosha T., DakiyoS., Laswai H. (1998) *Breastfeeding, weaning practices and anthropometric status of children in Morogoro district, Tanzania.* Ecol. Food Nutr, 37(4): 309–338.

Mosha T., LaswaiS, Tetens I (2000). Nutritional composition and micronutrient status of home made and commercial weaning foods consumed in Tanzania. *Plant Foods Hum Nutr., 55(3): 185-205.*

Muhimbula, H., Zacharia, I. and Kinabo J. (2011).Formulation and sensory evaluation of complementary foods from local, cheap and readily available cereals and legumes in Iringa, Tanzania *African Journal of Food Science.5(1): 26 - 31,*

Muhimbula, H. and Zacharia, I. (2010). Persistent child malnutrition in Tanzania: Risks associated with traditional complementary foods (A review*) African Journal of Food Science 4 (11): 679 – 692.*

Murray, J., Dulahuntry, C. and Baxter A. (2001). Descriptive sensory analysis: past, present and future. *Food research International,* 34: 461-471

Muyonga H, Tibagonzeka J,Wambete Muyinda M, and Nakimbugwe D. (2014).Acceptability and nutritional contribution of grain amaranth recipes in Uganda .*African journal of Food, Agriculture, Nutrition and Development.*(4): 3.

Mwanri L., Masika J. and Bundara N. (2013). Addressing childhood under nutrition in Tanzania: challenges and opportunities. *African Journal of Food, Agriculture, Nutrition and development. 13: (1).*

National Research Council (1984). Amaranth Modern Prospects for Ancient Crop. Washington DC: *National Academy Press*.

Navale, S. A., Swami, S. B., & Thakor, N. J. (2015). Extrusion Cooking Technology for Foods. *Journal of Ready to eat food 2 (3): 66–80 pp.*

Ndunguru, J. and Rajabu C. (2000).Incidence of sweet potato virus disease under different sweet potato cropping systems in the Lake Zone of Tanzania. *African Potato Association (APS) Conference Proceeding.*5: 405- 408.

Nkundabombi, M. G., Nakimbugwe, D., & Muyonga, J. H. (2015). Effect of processing methods on nutritional , sensory , and physicochemical characteristics of biofortified bean flour, (Ubos 2012). http://doi.org/10.1002/fsn3.301.

O` Brien, R. (2008). Fats and oils Analysis in fats and oils formulating and processing for applications, Third edition. CRC Press, Chapter of amaranth (Amaranthus caudatus L.) grown in East Africa. *African Journal of Food Science and Technology, 3*(6): 129-141.

of amaranth (Amaranthus caudatus L.) grown in East Africa. *African Journal of Food Science and Technology, 3*(6), 129-141

Ojinnaka, M., Ebinyasi, C., Ihemeje, A., and Okorie, S. (2013). Nutritional Evaluation of Complementary Food Gruels Formulated from Blends of Soybean Flour and Ginger Modified Cocoyam Starch, *African Journal of Food Science and Technology, 5* (10): 1325–1330.

Okoth, J., Ochola, S., Gikonyo, N., and Makokha, A. (2016). Development of a nutrient- dense complementary food using amaranth- sorghum grains, 1–8. http://doi.org/10.1002/fsn3.367

Oladimeji, O. (2015). Development and Optimization of Amaranth Based Instant Soup and Porridge Flours, College of Agricultural and Environmental Sciences. *Master`s degree thesis.* Makerere University, College of Agricultural and Environmental Sciences, School of Food Technology Nutrition and Bio- Engineerung.

Parvin, R., Satter, M., Jabin, S., Abedin, N., Islam, F., and Kamruzzaman, M. (2014). Studies on the Development and Evaluation of Cereal Based Highly Nutritive Supplementary Food for Young Children, *9*(2): 974–984.

Pelto GH, Levitt E, Thairu L (2003). Improving Feeding Practices: Current Patterns, Common Constraints, and the design of Interventions. *Food Nutrition. Bull.,* 24: 24-82.

Pongjanta, J, Naulbunrang, A, Kawngdang, S, Manon, T, and Thepjaikat, T. (2006). Utilization of pumpkin powder in bakery products. *Journal of Science and Technology, 28*:71-79.

Prakrati, R. Ameeta K. and Kushwah S. (1999).Effect of extrusion cooking variables on anti-nutritional components and in vitro protein digestibility of Faba Bean. *Indian Journal of Animal nutrition*. 16: 301-305

Ramachandra, H. and Thejaswini, M. (2015). Extrusion Technology : A Novel Method of Food Processing, *2*(4): 358–369.

Revathy, N. and Sabitha N. (2013). Development, quality evaluation and popularization of pumpkin seed flour incorporated bakery products. *International Journal of Food and Nutrition.*12 (2): 40-43.

Riaz, M., Anjum, F., and Khan, M. (2007). Latest trends in food processing using extrusion technology. *Pakistan Journal of Food Sciences*, *17*(1): 53–138.

Ruel T, Levin E, Armar-Klemesu M, Maxwell, G., Morris, S. (2009).Good care practices mitigate the negative effects of poverty and low maternal schooling on children's nutritional status: evidence from Accra. *World Development***,** 27:1993-2009.

Ruwaida Amed, Kirthee Pillay, Mathulisi Siwela and Unathi Kolanisi. (2016). Accepatance of a complementary food based on pro-vitamin A- Biofortified maize and chicken stew. J Hum Ecol, 55(3): 152-159.

Safari, J., Kimambo, C., and Lwelamira, J. (2013). Feeding practices and nutritional status of infants in Morogoro municipality, Tanzania. *Tanzania Journal of Health Research*, *15* (3): 1–10.

Saguy, I. and Karel, M. (1980).Modeling of quality deterioration during food processing and storage.*Journal of Food Technology*, 37: 78.

Shimelis, E., Rakshit, K. (2007). Effect of cooking and processing on antinutrients and in vitro protein digestibility of kidney bean ( *Phaseolus vulgaris L*) varieties grown in East Africa. *FoodChem*.103:161-172

Sind, K. and Wambugu, S. (2012). Going to scale with sweet potato vines distribution in Tanzania: Marando bora baseline study, milestone report OB3BMS2. ICI, Nairobi: CIP

Singh, D., and Maharaj, R. (2014).Sensory evaluation as a tool in determining acceptability of innovative product development by undergraduate students in Food Science and Technology at the University of Trinidad and Tobago.*Journal of curriculum and teaching*, 3(1): 10-27

Steel, C.J, Leoro, M.G.V, Schmiele, M, Ferreira, R.E, & Chang, Y.K. (2012).Thermoplastic Extrusion in Food Processing, Thermoplastic Elastomers.In P. A. El-Sonbati (Ed.), *InTech*. Croatia.

Sternin M, Sternin J, Marsh L. (1997).Rapid, sustained childhood malnutrition alleviation through a positive- deviance approach in rural Vietnam: preliminary findings, VA: BASICS, 49-61

Sundarrajan, L. (2014). Effect of extrusion cooking on the nutritional properties of amaranth, quinoa, kañiwa and lupine.(MSc.), University of Helsinki, Helsinki.

Tanzania Demographic and Health Survey (TDHS) 2010 Dar Es Salaam, Tanzania: National Bureau of Statistics and ORC Macro.

Tanzania Food and Nutrition Centre. (2014). Tanzania National Nutrition Survey, final report. Ministry of Health and Social Welfare, The United Republic of Tanzania.

Teutonico RA and D Knorr. (1985).Amaranth: composition, properties and applications of a rediscovered food crop. *Food Tech.;* 39: 49-61

Thaoge, M., Adam, M., Sibara, M., Waston, G., Taylor, N. and Goyvaerts M. (2003). Production of improves infant porridge from pearl millet using a lactic acid fermentation step and addition of sorghum malt to reduce viscosity of porridges with high protein, energy and solids ( 30%) content. *World Journal of microbiology and Biotechnology*, 19:305-310.

UNICEF (2017). Under nutrition contributes to nearly half of all deaths in children under 5 and is widespread in Asia and Africa. UNICEF Data: Monitoring the Situation of Children and Women. https://data.unicef.org/wp-content/uploads/2016/06/130565-1.pdf

UNICEF United Nations Children Fund (2011) Malnutrition, the silent emergency available at http//www.unicefusa.org/malnutrition.Accessed 23 Jan 2015.

UNICEF, (2009).Tracking Progress on Child and Maternal Nutrition. *A survival and development priority*: New York, NY 10017, USA

UNICEF, (2013). Joint statement on improving existing reccomendations on treatment of moderate malnutrition in children under 5. Geneva

United Nations Children Fund (UNICEF).(2010). How to feed a baby after 6 months. A brochure developed by University research Co., LLC in Tanzania, Kenya, Malawi and Uganda. NuLife Program: USAID Cooperative agreement 717-A-00-08-00006-00.

Victor O., Amadi B, Sinkala M, Felteu S. and Tomkins (2008) *African Journal of Food Agriculture Nutrition and Development*, 8 (1): 28-47.

Victor, I. A., Oguntuase, S. O., and Vincent, O. S. (2013). Physico-Chemical Properties of Complementary Food from Malted Quality Protein Maize ( Zea mays L . ) and Defatted Fluted Pumpkin Flour ( Telfairia occidentalis, *3*(6): 323–328.

Villapando S (2000). Feeding mode, infections, and anthropometric status in early childhood. Pediatrics, 106: 1282-1283.

Waized, B., Ndyetabula, D., Temu, A., Rabison E. and Spencer H. (2015).Promoting biofortified crops for Nutrition: Lesson from orange fleshed sweet potato (OFSP) in Tanzania. Sokoine University of Agriculture and Institute of development studies, UK.

World Food Program.(2012). Food quality control.www.wfp.org accessed 14$^{th}$ June 14, 2016

World Health Organization. (2009). Complementary feeding of young children in Developing Countries: A review of current Scientific Knowledge. WHO/NUT/98.1

World Health Organization. (2010). Summary of guiding principles for complementary feeding of the breastfed children Geneva, Switzerland

Yang, N., Hort, J., Linforth, R,.Brown K., Walsh, S. and Fisk, D. (2013). Impact of flavor solvent (propylene glycol or triacetin) on vanillin, 5- (hydroxymethyl) furfural, 2,4-decadienal, 2,4- heptadienal, structural parameters and sensory. Perception of shortcake biscuits over accelerated shelf life testing. *Food Chemistry*, 141: 1354-1360.

## APPENDICES

**Appendix 1: Sensory evaluation tool for product screening of soybeans, amaranth grains, pumpkin seeds and OFSP based porridge.**

**SENSORY EVALUATION OF PORRIDGE**

SEX: MALE ☐ FEMALE ☐ AGE ☐ DATE ☐

INTRODUCTION

You are provided with different porridge samples which you have to assess. Carefully start from left to right, observe the sample and assess them for; (i) Appearance (ii) Taste (iii) Color (iv) Smell (v)Texture (vi) General acceptability. Please indicate the number which best describes your feeling. Please take a sip of water and rinse your mouth before and after testing any sample.

| ATTRIBUTES | RANK | 802 | 412 | 334 | 739 | 281 | |
|---|---|---|---|---|---|---|---|
| Appearance | 9. Like extremely | | | | | | |
| | 8.Like very much | | | | | | |
| | 7. Like moderately | | | | | | |
| | 6. Like slightly | | | | | | |
| | 5. Neither like Nor dislike | | | | | | |
| | 4. Dislike slightly | | | | | | |
| | 3. Dislike moderately | | | | | | |
| | 2. Dislike very much | | | | | | |
| | 1 Dislike extremely | | | | | | |
| | | | | | | | |
| Taste | 9. Like extremely | | | | | | |
| | 8.Like very much | | | | | | |
| | 7. Like moderately | | | | | | |
| | 6. Like slightly | | | | | | |
| | 5. Neither like Nor dislike | | | | | | |
| | 4. Dislike slightly | | | | | | |
| | 3. Dislike moderately | | | | | | |
| | 2. Dislike very much | | | | | | |
| | 1. Dislike extremely | | | | | | |
| | | | | | | | |
| Aroma | 9 Like extremely | | | | | | |
| | 8.Like very much | | | | | | |
| | 7. Like moderately | | | | | | |
| | 6. Like slightly | | | | | | |
| | 5. Neither like Nor dislike | | | | | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 4. Dislike slightly | | | | | | | |
| | 3. Dislike moderately | | | | | | | |
| | 2. Dislike very much | | | | | | | |
| | 1. Dislike extremely | | | | | | | |
| | | | | | | | | |
| Texture | 9. Like extremely | | | | | | | |
| | 8.Like very much | | | | | | | |
| | 7. Like moderately | | | | | | | |
| | 6. Like slightly | | | | | | | |
| | 5. Neither like Nor dislike | | | | | | | |
| | 4. Dislike slightly | | | | | | | |
| | 3. Dislike moderately | | | | | | | |
| | 2. Dislike very much | | | | | | | |
| | 1. Dislike extremely | | | | | | | |
| | | | | | | | | |
| General acceptability | 9. Like extremely | | | | | | | |
| | 8.Like very much | | | | | | | |
| | 7. Like moderately | | | | | | | |
| | 6. Like slightly | | | | | | | |
| | 5. Neither like Nor dislike | | | | | | | |
| | 4. Dislike slightly | | | | | | | |
| | 3. Dislike moderately | | | | | | | |
| | 2. Dislike very much | | | | | | | |
| | 1. Dislike extremely | | | | | | | |

Kindly provide more comments about this product.

**Appendices 2:** Sensory evaluation for shelf life stability tasting.

**SENSORY EVALUATION OF PORRIDGE**

SEX: MALE [ ] FEMALE [ ] AGE [ ] DATE [ ]

INTRODUCTION

You are provided with different porridge samples which you have to assess. Carefully start from left to right, observe the sample and assess them for; (i) Appearance (ii) Taste (iii) Color (iv) Smell (v)Texture (vi) General acceptability. Please indicate the number which best describes your feeling. Please take a sip of water and rinse your mouth before and after testing any sample.

| ATTRIBUTES | RANK | 125 | 317 | 420 | 666 | 188 | |
|---|---|---|---|---|---|---|---|
| Appearance | 9. Like extremely | | | | | | |
| | 8.Like very much | | | | | | |
| | 7. Like moderately | | | | | | |
| | 6. Like slightly | | | | | | |
| | 5. Neither like Nor dislike | | | | | | |
| | 4. Dislike slightly | | | | | | |
| | 3. Dislike moderately | | | | | | |
| | 2. Dislike very much | | | | | | |
| | 1 Dislike extremely | | | | | | |
| | | | | | | | |
| Taste | 9. Like extremely | | | | | | |
| | 8.Like very much | | | | | | |
| | 7. Like moderately | | | | | | |
| | 6. Like slightly | | | | | | |
| | 5. Neither like Nor dislike | | | | | | |
| | 4. Dislike slightly | | | | | | |
| | 3. Dislike moderately | | | | | | |
| | 2. Dislike very much | | | | | | |
| | 1. Dislike extremely | | | | | | |
| | | | | | | | |
| Aroma | 9 Like extremely | | | | | | |
| | 8.Like very much | | | | | | |
| | 7. Like moderately | | | | | | |
| | 6. Like slightly | | | | | | |
| | 5. Neither like Nor dislike | | | | | | |
| | 4. Dislike slightly | | | | | | |
| | 3. Dislike moderately | | | | | | |
| | 2. Dislike very much | | | | | | |
| | 1. Dislike extremely | | | | | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Texture | 9. Like extremely | | | | | | | |
| | 8.Like very much | | | | | | | |
| | 7. Like moderately | | | | | | | |
| | 6. Like slightly | | | | | | | |
| | 5. Neither like Nor dislike | | | | | | | |
| | 4. Dislike slightly | | | | | | | |
| | 3. Dislike moderately | | | | | | | |
| | 2. Dislike very much | | | | | | | |
| | 1. Dislike extremely | | | | | | | |
| | | | | | | | | |
| General acceptability | 9. Like extremely | | | | | | | |
| | 8.Like very much | | | | | | | |
| | 7. Like moderately | | | | | | | |
| | 6. Like slightly | | | | | | | |
| | 5. Neither like Nor dislike | | | | | | | |
| | 4. Dislike slightly | | | | | | | |
| | 3. Dislike moderately | | | | | | | |
| | 2. Dislike very much | | | | | | | |
| | 1. Dislike extremely | | | | | | | |

Kindly provide more comments about this product.

**Porridge samples made in this study**

**Porridge from formulation 1-5**