EVALUATION OF NUTRITIONAL AND SENSORY QUALITY OF ORANGE FLESHED SWEET POTATO PORRIDGE ENRICHED WITH SOYBEAN AND MORINGA LEAVES

M.Sc. THESIS

BY

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JIMMA UNIVERSITY

EVALUATION OF NUTRITIONAL AND SENSORY QUALITY OF ORANGE FLESHED SWEET POTATO PORRIDGE ENRICHED WITH SOYBEAN AND MORINGA LEAVES

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Decision/suggestion of Department Graduate Council (DGC)

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DEDICATION

This work is dedicated to my beloved Grandmother and Uncle.

STATEMENT OF THE AUTHOR

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BIOGRAPHICAL SKETCH

The author Tirhas Mebratu was born from her father Mr. Mebratu G/Tsadikan and mother Mrs. Medhen Zekarias in Axum on September 16, 1988 G.C. She attended and completed elementary education at Eweket Fana and Waliya elementary school in Addis Ababa (1996-2002), grade 9 to 10 at Shimels Habte secondary school (2003-2004) and grade 11 to 12 at Abiyot Kires preparatory school (2005-2006). She joined Jimma University College of Agriculture and Veterinary Medicine, in September 2007 and graduated with B.Sc degree in Crop science in June 2010. In September 2010, she joined the school of graduate studies at Jimma University to pursue her graduate study in the Department of Post Harvest Management.

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LIST OF ABBREVIATIONS AND ACCRONYMS

AAS	Atomic Absorption Spectrophotometer
BMI	Body Mass Index
EHNRI	Ethiopian Health and Nutrition Research Institute
FAO	Food and Agriculture Organization
IDA	Iron Deficiency Anemia
ID	Iron Deficiency
JUCAVM	Jimma University College of Agriculture and Veterinary Medicine
LBW	Low Birth Weight
OFSP	Orange Fleshed Sweet Potato
PEM	Protein Energy Malnutrition
RDA	Recommended Dietary Allowance
RE	Retinol Equivalente
VAD	Vitamin A Deficiency
WHO	World Health Organization

ABSTRACT

Pregnant and lactating women in underdeveloped countries like Ethiopia are highly vulnerable for malnutrition in macronutrients, micronutrients or both. To alleviate this problem, Composite flour is commonly used method to make use of local raw material to produce high quality food products in an economical way. Thus, this study was designed in order to investigate the nutritional and sensory quality of porridge developed from different proportions of orange fleshed sweet potato (60-85%), enriched with soybean (10-30%) and moringa leaves (5-10%). The proportions of ingridients were selected using 16-run, three-level D-Optimal constrained mixture design. Porridge or Gruel obtained from mixture of the three ingredients was evaluated for proximate composition, total carotenoid, minerals, functional properties and sensory attributes. The results showed significant differences (p<0.05) among the products of different blending ratio of ingredients in protein, total ash, fiber, iron, calcium, water absorbing capacity, tannin and sensory attributes. On the other hand there were no significant differences among the products in terms of total carotenoid, crude fat, carbohydrate, bulk density, viscosity, water activity and phytate contents. Gruel prepared from higher proportion of OFSP, soybean and lower levels of moringa showed better sensory acceptability though high proportion of moringa improved nutritional quality of the products. The result revealed that OFSP, soybean and moringa have good potential for making vitamin A-protein-iron enriched thin porridge (gruel). Graphical optimization showed that the product containing 67-75% OFSP, 17-23% soybean, and 5-8% moringa is the best formulation to yield nutrient enriched gruel with desirable sensory attributes. This product has a potential benefit for long term food-based strategy for controlling vitamin A and iron deficiencies in pregnant and lactating women in developing countries.

Key words: Composite flour, Porridge/gruel, Moringa leaves, Malnutrition, OFSP, Soybean

1. INTRODUCTION

The health of human beings depends on diets that include adequate amounts of vitamins and minerals to promote effective physiological processes such as reproduction, immune response, brain and other neural functions, and energy metabolism (FMH, 2004). Ideally, a good nutrition is assured by diet diversification of food like animal products, root and tubers, grain, fruit and vegetables (FMH, 2008). However, in reality, varieties of diet sources that are good in nutrition are unaffordable or seasonally unavailable for majority of the world's population which leads to malnutrition problem (FMH, 2004).

Malnutrition is frequently observed and become a serious public health problem linked to a substantial increase in the risk of mortality (Sandra and Dominic, 2011). The problem of malnutrition is associated with deficiencies of macronutrients (protein, carbohydrates and fat) or micronutrients (minerals and vitamins) or both (Uthman and Aremu, 2008). Particularly, micronutrient malnutrition is widespread in the industrialized nations and more in the developing regions like Ethiopia. It can affect all age groups, but young children and women of reproductive age tend to be among those most at risk of developing micronutrient deficiencies (WHO/FAO, 2006).

Most women in developing countries like Ethiopia are vulnerable to malnutrition throughout the life cycle such as undernourished at birth, stunted during childhood, underfed and overworked during pregnancy as well as breast feeding FMH (2008). According to the Demographic and Health Survey (DHS) (Central Statistical Agency, 2005), over one-quarter of women are chronically malnourished (BMI <18.5 cm) and three-in-ten women and adolescent girls aged 15–19 are undernourished. The Federal Ministry of Health (FMH) (2003) also reported that the risk of malnutrition appears on the 58 % death rate of child, about 29 % malnutrition prevalence among breast feeding mothers and 5-15 % prevalence of vitamin A deficiency diseases (night blindness) among the pregnant women.

However, Ethiopia has the capacity to produce different agricultural products which helps to be food self sufficient that can fully give the daily requirement of the balanced diet. Nevertheless, the people are not accustomed to vary their meal to fulfill their nutritional requirements. This seems due to the lack of knowledge on the balanced diet, limited income to purchase foods and lack of awareness on cheap, locally available and nutritionally rich underutilized crops. Creating awareness and producing products from the underutilized crops seem to be important to reduce the problem of malnutrition. There are different underutilized crops growing in Ethiopia including sweet potato (orange fleshed), soybean and moringa (*Shiferaw*).

Orange fleshed sweet potato (OFSP) is adaptable to diverse environments, high in yields and available all year round. OFSP is the most promising crop sources of β-carotene which are believed to represent the least expensive, year-round source of dietary vitamin A. Regular utilization of OFSP, therefore, could potentially make a major contribution to overcoming vitamin A deficiency in East and Southern Africa (Tomlins et al., 2007). However, it has relatively low protein content which can be obtained from pulses like soybean. Soybean is protein and oil rich crop that is cultivated in Ethiopia for both local and export purpose. Due to its vegetable protein source nature, it lowers cholesterol levels in patients. Soybean-fortified products are considerably cheaper than other sources of high quality protein, such as fish, meat, milk and other protein-rich legumes. Thus, Soybean is suitable to areas where other protein sources are unavailable or too expensive (Malema, 2005) like in most of Ethiopian areas.

There are other crops include moringa that supplement nutrients which are little in OFSP and soybean. Moringa is the tropical drought resistant tree that is suitable for home gardening and provides continuous fresh leaves (Broin, 2006). It has great potential to become the most economically important tree crops for either tropics or subtropics due to its properties, which offer nutritious food, medicine, and source of income. Since the commodity contains very strong concentration of macro- and micro-nutrients, it is very important to reduce malnutrition problem (Kumalaningsih et al., 2011). Hence, moringa leaves have been promoted as a potential locally accessible high quality food due to high content of iron and other nutrients (Melesse et al., 2011).

Since most Ethiopian society's diet is mainly cereal based, which is limited in essential nutrients, food-based strategies favoring local multi-nutrient food materials are the best suitable and sustainable strategies for combating malnutrition (WHO/FAO, 2006). Complementation of local multi-nutrient food materials like OFSP, soybean and moringa that are rich in beta carotene, protein and iron respectively can be useful to solve the problem in most vulnerable groups.

Therefore, a diet of poor nutritional quality during pregnancy weakens women's ability to survive during childbirth and give birth to a healthy child. It results in serious problems in growth, psychosocial development and learning capacity of children and lost lives of mothers and their infants. It also undermines women's productivity, income generating capacity, and their contribution to their families (Sandra and Dominic, 2011). Hence, the nutritional demands during pregnancy and lactation are multiple to support fetal growth and breast milk production; the devastating effects of malnutrition of essential nutrients in those vulnerable groups are needed to be addressed. This can be done by blending locally available and cheap crops through locally known food type like thin porridge. Considering their respective nutrients sources such as OFSP (vitamin A), soybean (protein) and moringa leaves (iron), blending of them through optimum amount can be assumed as a good option for alleviating the major macro- and micro-nutrients malnutrition in pregnant and lactating women.

General objective:

The main objective of this study was to investigate the quality of gruel prepared from orange fleshed sweet potato enriched with soybean and moringa leaves.

Specific objectives:

- To determine nutrient contents of the porridge,
- To determine selected anti-nutrients contents of the porridge,
- To determine the sensory acceptance of the porridge,
- To find the optimum blending ratio of orange fleshed sweet potato porridge enriched with soybean and moringa leaves.

2. LITERATURE REVIEW

2.1 Malnutrition

Malnutrition refers to an impaired health resulting from under nutrition a lack of nutrients or from over nutrition which is excessive intake of nutrients. Malnutrition also may result from poor absorption or biological use of nutrients consumed due to illness, disease, or nutrient imbalances (Benson, 2005). Many factors can also cause under-nutrition, most of which relate to poor diet or severe and repeated infections, particularly in under privileged populations. Inadequate diet and disease, in turn, are closely linked to the general standard of living, the environmental conditions, and whether a population is able to meet its basic needs such as food, housing and health care. Thus, malnutrition is a health outcome as well as a risk factor for disease and aggravated the effects, and it can increase the risk of morbidity and mortality (Blössner and de Onis, 2005).

Under nutrition is widespread in the developing countries such as Asia, Africa and Latin America, in which about 25 % - 30 % of their population suffering from semi-starvation (Armar Klemesu and Wheeler, 1991). However, throughout the world it is estimated 400 million people suffer from serious nutritional deficiencies (Ojofeitimi, 1992). In Ethiopia, malnutrition is observed as sever problem in women and children (FMH, 2008).

2.2 Classification of malnutrition

Malnutrition can be broadly classified as macro- and micro-nutrients malnutrition based on the amount of nutrient. Every category has important nutrients such as protein, carbohydrate and fats under macronutrients and vitamins and minerals under micronutrients. The deficiency of each nutrient that belonging in both categories cause a serious malnutrition in human being.

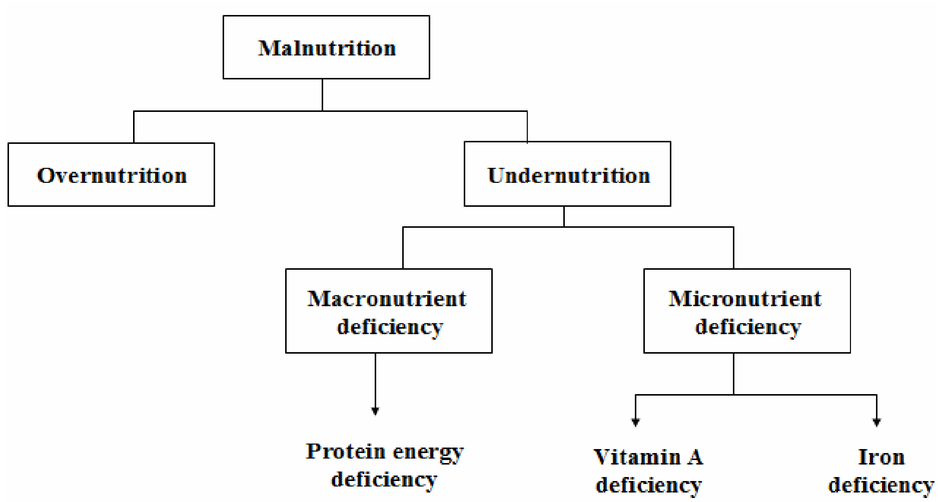


Figure 1. Classification of malnutrition with major nutrients deficiencies (modified from WHO/FAO, 2006).

2.2.1 Micronutrient malnutrition

This malnutrition type is also called a 'hidden hunger' as the consequences. It embraces deficiencies of different type of vitamins, minerals. Frequent occurrence of micronutrient deficiencies has been observed worldwide, particularly in developing world where quality and variety of foods are limited (WHO/FAO, 2006). Some of these major deficient micronutrients are vitamin A and iron.

Vitamin A deficiency (VAD): Vitamin A is an essential nutrient that is required in small amounts by humans for the normal functioning of the visual system, the maintenance of cell function for growth, epithelial cellular integrity, immune function and reproduction (WHO/FAO, 2006). Although vitamin A is an essential for human being, the deficiency is a serious bottleneck in most developing countries.

VAD occurs when vitamin A intake or liver stores fail to meet daily metabolic requirements and the most common cause is a persistently low intake of vitamin A-rich foods; when there is a problem with absorption, conversion or utilization of vitamin A (FMH, 2004). VAD exists in pregnant and breast feeding women in many areas of Africa. For instance, in Zambia and Tanzania, 22 % of mothers are deficient in vitamin A and 69 % of women are deficient in levels of vitamin A in breast milk, respectively (USAID, 2001). Its deficiency has long been known to cause blindness, but, recently studies report that vitamin A deficiency is closely associated with increased mortality and morbidity among young children (FMH, 2004).

In order to tackle VAD, daily nutritional needs of vitamin A for different age-group have been evaluated (Table1). The mean requirement intake, which is the minimum intake, prevents xerophtalmia in the absence of clinical or sub-clinical infection (Bechoff, 2010). The recommended safe intake that is the average intake of vitamin A permits adequate growth and other vitamin A dependent functions and maintain an acceptable total body reserve of the vitamin. Recommended safe intake is also known as Recommended Dietary Allowance (RDA).

Table 1. Estimated mean requirement and safe level of intake for vitamin A.

Age group	Mean requirement (µgRE/day*)	Recommended safe intake (µgRE/day)
Infants and children		
0-6 months	180	375
7-12months	190	400
1-3 years	200	400
4-6 years	200	450
7 years	250	500
Adolescents,10-18 years	330-400	600
Adults		
Females,19-65 years	270	500
Males,19-65 years	300	600
65+	300	600
Pregnant women	370	800
Breast feeding women	450	850

* Microgram retinol equivalents per day. Source: Bechoff (2010)

Iron deficiency (ID): Most of the iron in the human body is present as haemoglobin. Haemoglobin is necessary for transporting oxygen to tissues and organs in the body. Iron is also an important component of various enzyme systems, such as the cytochromes, which are involved in oxidative metabolism (WHO/FAO, 2006). However, the prevalence of iron deficiency has been observed frequently in human being. Anaemia is a condition characterized by a low level of haemoglobin in the blood. About half of the global burden of anaemia is due to iron deficiency. Iron deficiency, in turn, is largely due to an inadequate dietary intake of bioavailable iron, inadequate dietary iron during periods of increased iron requirements (such as pregnancy and infancy), increased blood loss due to hookworm infestation, and infections such as malaria (Central Statistical Agency, 2011).

It has also been observed that the prevalence of iron deficiency and its severity is considerably greater in women during their reproductive years than in men (Haidar et al., 2003). Non-pregnant women need about 1.2 mg of iron per day to meet basal needs and replace iron lost during menstruation. Pregnancy causes loss of iron for fetal tissue formation and increased blood supply Table 2 (USAID, 2001). It also occurs among malnourished population and is particularly severe in under-five year old children and adolescent populations (Haidar et al., 2003).

Table 2. Basal iron requirement and losses of woman.

Source	Iron cost(mg/day)
Basal iron requirement	0.72
Iron loss through menstruation	0.44
Iron loss through pregnancy	2.14
Iron loss through lactation	0.23
Iron loss through moderate hookworm infection	
N. americanus	1.10
N. duodenale	2.30

Source: USAID (2001)

In developing countries, around 50 % of pregnant women are anemic. Severely anemic women are at increased risk of death in pregnancy such as 13 % of maternal deaths in Asia and 4 % in Africa are directly caused by anemia (Yang and Huffman, 2011).

Although the magnitude of iron deficiency anemia (IDA) in Ethiopia has not yet been well documented nationwide, limited data is available on the prevalence rate of IDA among pregnant and breast feeding women in the rural communities, which showed a prevalence rate of 18.7 % (Haidar et al., 1999). In a more recent study conducted in urban slum communities of Addis Ababa administrative region, a prevalence rate of 22.3 % was reported in breast feeding women suggesting that iron deficiency anaemia is of moderate public health problem in the country (Haidar et al., 2003). The majority of anaemic women were in the category of mild (19.3%) to moderate (10.3 %) and severe anaemia was 0.9 %. The most affected age groups were those between 36-49 years and the difference noted was statistically significant (Umeta et al., 2008).

2.2.2 Macronutrient malnutrition

Macronutrient malnutrition is also known as protein energy malnutrition (PEM), which is an imbalance between the supply of energy and protein, and the body's demand for them to ensure optimal growth and function. It is currently the most widespread and serious health problem of children in the world being the moderate or severe forms (USAID, 2002). The prevalence rates will be influenced by season, the availability of food, incidence of infection and the state of development of the health services in any country (Armar, 1989). Similar to the case for young children, protein-energy malnutrition in adults is difficult to define. Anthropometric indicators are actually all that is usually measured as indicators. Arm circumference is of increasing interest, but most studies have used weight, height or body mass index (Merchant et al., 1992). In Africa, the prevalence of maternal underweight is above 20 % in Chad (22.6 %), Ethiopia (23.8 %) and Madagascar, (28.2 %) and the highest rates are found in South Asia (India 39.9 %, Bangladesh 32.8 % and Nepal 26.1 %) (Yang and Huffman, 2011).

2.3 Nutritionally vulnerable groups

2.3.1 Women

The nutritional status of women is a major determinant of both maternal and infant health. Women and children are often more vulnerable to malnutrition than men. This is particularly in the developing countries where women are known to be underfed and at the same time overworked both on the farm and in household chores (Madukorsiri et al., 2009). Additionally menstruation, pregnancy and lactation can lead to nutritional deficiency, which is the most widespread and disabling health related problem among women (Haseen, 2003). As a result, malnutrition is responsible for a broad range of short and long-term negative consequences for women, including increased reproductive risk, morbidity, and mortality. Women's nutritional status affects the morbidity and mortality of children through its impact on birth weight, prematurely, and nutrient stores in infants. In addition, under nutrition diminishes women's productivity, income-earning capacity, and educational achievement (USAID, 2001).

The vulnerability of women to malnutrition is heightened during conditions of pregnancy and lactation-periods characterized with increased nutritional needs as a result of induced stress (Madukorsiri et al., 2009). The combination of chronic energy deficiency, poor weight gain in pregnancy, anemia, and other micronutrient deficiencies, infections such as HIV and malaria, and inadequate obstetric care contribute to high rates of maternal mortality throughout most countries in Africa (USAID, 2001). Some evidences in developing countries indicate that malnourished individuals, that is, women with a body mass index (BMI) below 18.5, show a progressive increase in mortality rates as well as increased risk of illness (Girma, and Genebo, 2002). According to Dewan (2008), percentage wise malnourished females in India are 25.2 % as compared to males (20.2 %).

A study conducted in Southwestern Ethiopia indicated that 19.4 % of the women were below BMI cut-off points of 18.5 (Demissie et al., 2003). Another study undertaken in Hadiya zone in 1995 indicated that nearly 90 % of pregnant women were below the recommended anthropometric standards (Demissie, 1995).There is clear evidence that mother's nutritional status is directly correlated with the nutritional status of the children (Begum and Sen, 2005). Intrauterine growth retardation (IUGR) largely due to maternal malnutrition prior to and during pregnancy causes about two-thirds of low birth weight in developing countries. In more than 70 percent of the sub-Saharan countries, 10 percent or more of babies were born with low birth weight (LBW), as reported by their mothers (USAID, 2001).

2.3.2 Children

Child malnutrition is a serious public health problem (Gibson et al., 2009), especially in the poorest countries like Sub-Saharan Africa. The poorly nourished child is highly susceptible to infection, and infections are more severe and last longer in malnourished than in a well nourished child. The child is then more vulnerable to next infectious disease to which he or she is exposed. Because of the nutrients in the food cannot be absorbed from the intestinal tract a child who has frequent bouts of diarrhea may be poorly nourished (Armar Klemesu and Wheele, 1991).

According to the Demographic and Health Survey (DHS) data, 29% of Ethiopian children are underweight and 9% are severely underweight and it also indicates that nearly 45% are stunted and 10% are wasted (Central Statistical Agency, 2011).The growth patterns of a child are useful means for judging nutritional well-being. When a child is poorly nourished, the growth rate diminishes particularly because of delay in bone development (Ojofeitimi, 1992; Armar, 1989). Both the quality of the bone (the amount of calcium and phosphorus it contains) and its capability for growth is influenced by nutrition. Sexual maturity appears to occur late in populations that are malnourished than in the developed countries (Armar Klemusu and Wheeler, 1991).

Breast feeding pattern of children under six months is found as an important factor linked with malnutrition in North Wollo, Ethiopia (Belachew, 2005 and reference therein). The ability to exclusively breastfeed depends on whether or not a mother can spend sufficient time with her child as well as the knowledge that exclusive breastfeeding is best for children aged 0-6 months. Women who spend more than two hours away from their children aged less than six months are significantly less likely to exclusively breastfeed than other mothers are. Malnutrition increases very rapidly between 5-10 months in this population.

Although all mothers breastfeed their newborns, 11% of infants less than six months of age are already stunted. Malnutrition rates continue to rise to 12-23 months of age, resulting in stunting in nearly 60% of children and wasting in about 20%. From that period onwards about 60% of children remain stunted and about 10% of children remain wasted (Belachew, 2005 and reference therein).

2.4 Composite flour for alleviation of malnutrition

Food based strategies are most effective and sustainable approach to combat malnutrition. These require thorough knowledge of the sources of nutrients and their accessibility to humans. There are different strategies to prevent malnutrition, like food diversification, supplementation, food fortification and composite flour (Hurrell, 1997; WHO/FAO, 2006). The use of composite flour is one of the common food based strategies in preparing different products such as bread and it becomes imperative for developing countries which are affected by increasing cost of imported wheat (Owuamanam, 2007).

Composite flour strategy defines as the process of a binary or ternary mixture of several flours to make use of local available raw material to produce high quality food products economically. Mixing wheat flour with other crops flour as composite flour is vital for development of value-added products with optimal functionality (Rehman et al., 2007; Shittu et al., 2007). It can also be used to mix flour obtained from various plants rich in starch such as cassava, yams, sweet potatoes, protein-rich flours such as soy and peanuts, and other cereals including maize, rice, millet and sorghum with or without wheat flour (Khalil et al., 2000).

Several attempts has been done to promote the use of composite flour in which flour from locally grown crops and nutritionally rich crops, thereby reduces costs of importation and produces high quality product, for instance replacing the sole use of wheat for bread production (Giami et al., 2004; Olaoye et al., 2006). There are several crops, which are nutritionally rich and underutilized such as orange flesh sweet potato, soybean, moringa, cassava and so on, using as a substitute for nutrition improvement in Ethiopia (Kalekristos, 2010). Hence, formation of composite flour using flour from orange flesh sweet potato, soybean and moringa and developing gruel can be used to alleviate malnutrition problem in lactating women and their children.

2.5 Nutrional composition of composites

2.5.1 Orange fleshed sweet potato (OFSP)

Sweet potato (*Ipomea batata* Lam.) is a dicotyledonous plant, which is from the *Convolvulacae* family. It is an important crop in food systems in Eastern and Southern Africa. It is cultivated in more than 100 countries, it ranks third of the world root and tuber crops production after potato and cassava (Bechoff, 2010). It is adaptable to diverse environments, has high yields, performs well in marginal soils, is available all year round and is cheap to grow. In countries with two rainy seasons, it is available 11 months a year. In most other sub-Saharan African countries, sweet potato is a secondary staple, with one dominant growing season that appears from 4 to 8 months a year (Low and Van Jaarsveld, 2008 and references therein). This period is depending on whether households can access lowland areas with sufficient moisture to sustain a dry season crop and the maturity period of available varieties. Globally, sweet potato is an important staple food or base material for variety of food and industrial applications (Nandutu and Howell, 2009).

Sweet potato varieties such as white, pink and yellow (orange)-fleshed sweet potatoes are varied by their nutrient composition and its functional uses. Few years ago, white-fleshed sweet potatoes are commonly cultivated in sub-Saharan Africa, but orange-fleshed varieties are rarer (Ameny and Wilson, 1997). Adoption of OFSP, therefore, could potentially make a major contribution to tackle vitamin A deficiency in East and Southern Africa (Tomlins et al., 2007).

Nutritional composition: Sweet potatoes are rich in starch, complex carbohydrates, dietary fiber, ß-carotene, vitamin C and B_6 (Table 3), which are depends upon varieties. Particularly, yellow (orange)-fleshed sweet potato varieties are potentially excellent raw materials because of their high ß-carotene content (Woolfe, 1992). Orange fleshed sweet potato (OFSP) is the most promising plant sources of β-carotene which are believed to represent the least expensive, year-round source of dietary vitamin A. Current varieties of OFSP contain 20-30 times more β- carotene than does golden rice; the outstanding features of orange fleshed sweet potato are nutritional, compositional and sensory versatility in terms of its micronutrient contents and wide range of colors, taste and textures (Esther et al., 2010).

Table 3. Nutritional values of fresh orange fleshed sweet potato.

Nutrients	Amount/100g	Nutrients	Amount (mg /100g)
Protein (g)	1.7	Vitamin C	25
Fat (g)	0.1	Calcium	28
Fiber (g)	3.0	Iron	0.5
Carbohydrate (g)	21.3	Zinc	0.29
Vitamin A (µg RAE)	809		

Source: Faber et al., (2010).

Uses: Methods of traditional preparation of sweet potato in sub-Saharan Africa are limited to boiling, steaming, roasting and drying. Using a diagnostic assessment approach based in developing countries, dried products (chips, starch, and flour) were identified as the most promising products from sweet potato compared to the many options available. Its flour has been used to substitute other flours, such as cassava, wheat, and sorghum and can develops products from dried OFSP for sub-Saharan Africa include porridge, bread, bakery products such as mandazi (traditional doughnut), chapatti, cake etc (Bechoff, 2010). According to Low and van Jaarsveld (2008), 38 % of wheat flour by weight replaced with boiled and mashed fresh roots of orange fleshed sweet potato of medium orange intensity in recipes used by rural bakers in Central Mozambique is an economically viable product that has enough β-carotene content to be regarded as a good source of vitamin A. Several research findings are reported about supplement of OFSP in foods to complement vitamin A needs in different target groups (Adenuga, 2010; Adeleke and Odedeji, 2010; Amagloh et al., 2011).

2.5.2 Soybean

Soybean (*Glycin max*.) is a legume and cultivated in many areas of the world, from tropics to temperate regions. Soybean is become a widely used staple food of great nutritional value as a source of dietary protein and oil by millions of people, and in the industrial manufacture of thousands of products (Fabiyi, 2006). Its protein content (29.5-50.3%) is higher and more economical than that of beef (18%), chicken (20%), fish (18%) and groundnut (23%) (IITA, 1990). Since soybean is a vegetable protein source, it provides additional merit by lowering cholesterol levels in patients with type II hyperlipoproteinaemia (Sirtori et al., 2000).

According to Jimoh and Olatidoye (2009) findings, fortifying yam flour with soy bean flour at 10 % level would reduce the problem of food security especially among children in the sub Sahara region of Africa where malnutrition due to protein deficiency is common. Fabiyi (2006) also reviled that the fortification of cassava flour with full fat soybean flour at 10 % level would produce a more nutritionally balance and acceptable product which will reduce problem of food security among children in Nigeria where malnutrition due to protein deficiency is prevalent. Therefore, soybean is suitable to areas where other protein sources are unavailable or too expensive (Malema, 2005).

Nutritional composition: Soybean is rich in protein (29.6-50.3%), carbohydrate (32%), fat (20%), fiber (3%) and minerals/vitamins (5%) (Tinsley, 2009). It also contains low saturated fatty acids and free of cholesterol. The nutritional contents of soybean seed (Table 4) vary considerably according to the cultivar, origin of seed, climate and soil. Soybean varieties of low fibre content of less than 5% correlated with higher protein levels. There is also a significant variation in amino acid content depends on the cultivars and origin of the seed, but soybeans are relatively low sulphur containing amino acids that is cysteine and methionine (Asiedu, 1989).

Table 4. Nutritional content of soybean.

Composition	**Amount per 100g**
Moisture	8.54 g
Protein	36.49 g
Carbohydrate	30.16 g
Ash	4.87 g
Fiber	9.300 g
Total lipid	19.94 g
Iron	15.70 mg
Calcium	277.0 mg
Zinc	4.89 mg

Source: Tinsley (2009)

Uses: Soybean has several uses. They are processed to give soy milk, soy sauce, tofu (soybean curd) yogurt, soybean sprout, tempeh (soy steak), which is extensively used in the Far East as infant feeding. The seed yield edible, semi-drying oil which is extensively used in the Far East as food. The bulk of the oil is used for edible purposes particularly as a salad oil or in the manufacture of margarine, shortening and soy meal. The residues after the extraction of the oil is a very rich protein feeding stuff for livestock and for the manufacture of synthetic fibre, textile sizes and fire fighting foam (IITA, 1990). Soybean flour prepared from whole soybeans is used in bakery and other food product extends to cereal flour, meat products and in health foods (Fabiyi, 2006). Soybean flour is becoming increasingly important as an ingredient of food stuffs and bakery products such as bread, biscuits and cakes. Soybean-fortified products are considerably cheaper than other sources of high quality protein, such as fish, meat, milk and other protein-rich legumes. The cost of protein, when purchased as soybean, is only about 10-20 % of the cost of protein from fish, meat, eggs or milk (IITA, 1990).

2.5.3 Moringa leaves

Moringa species, which are the tropical drought resistant tree, are native to India and currently distributed in Africa and South America countries. It is a deciduous tree or shrub, fast growing, drought resistant, average height of 12 meters at maturity. It is suitable for home gardening, as it is easy to grow and provides continuous fresh leaves. The leaves are consumed raw, cooked as other green leaves or as a dried, concentrated powder (Broin, 2006). Currently, Moringa leaves are eaten traditionally in different Africa countries such as Niger, Nigeria, Senegal and Ethiopia.

Nutritional composition: Moringa leaves have been promoted as a potential cheap and locally accessible high quality food. It has been reported that the leaves have an unusually high content of calcium, iron, and vitamin- A (Table 5) (Melesse et al., 2011). However, the nutrient contents of Moringa leaves are inconsistent (Lockett, 2000), indicating different pre- and post harvest procedures, varieties, leaf age, etc.

Table 5. The nutritional compositions of moringa leaves

Chemical parameters	Leaf powder	Chemical parameters (mg)	Leaf powder
Moisture (%)	7.50	Mg	368.00
Calories	205.0	P	204.00
Protein (g)	27.10	K	1,324.00
Fat (g)	2.30	Fe	28.20
Carbohydrate (g)	38.20	Vitamin A-(beta-carotene)	16.30
Fiber (g)	19.20	Vitamin C-ascorbic acid	17.30
Ca (mg)	2,003.00		

Source: Yisehak et al (2011)

Uses: Moringa has great potential to become the most economically important tree crops for either tropics or subtropics due to its properties, which offer nutrition food, clean water, medicine, and income. Since the commodity contain very strong concentration, iron, Ca, protein and high essential amino acid, it is very important for releasing extend of malnutrition problem (Kumalaningsih et al., 2011). In the Philippines, it is known as 'mother's best friend' because of its utilization to increase milk production in breastfeeding women and is sometimes prescribed for anemia (Jongrungruangchok et al., 2010). According to Price (2007), for pregnant and breast-feeding women, moringa leaves and pods can carry out much to preserve the mother's health and pass on strength to the fetus or nursing child. A woman could get over a third of her daily need of calcium and her important quantities of iron, protein, copper, sulfur and B-vitamins from 100 g portion of leaves (Table 6).

Table 6. Nutrition compared to moringa leaf powder and other diet

Fresh	Dried leaf powder
4 time vitamin A of carrot	10 time vitamin A of carrot
7 time vitamin C of orange	½ time vitamin C of orange
4 time calcium of milk	17 time calcium of milk
3 time potassium of banana	15 time potassium of banana
¾ time iron of spinach	25 time iron of spinach
2 time protein of yogurt	9 time protein of yogurt

Source; Dolcas, (2008)

Since moringa is rich in various nutrients, its leaf powder is introduced in infant cereal to increase its mineral contents like iron, protein and vitamin (Broin, 2006). Moringa leaves are also a staple food for Konso people in Ethiopia. Moringa tree (also known locally as aleko or shiferaw) is used for a variety of purposes in southern Ethiopia. The leaves of *Shiferaw* are cooked and eaten, for example, with the traditional *kurkufa* (cereal preparation from maize and sorghum). The people of Konso and the surrounding communities in southern Ethiopia rely on the plant both as food and to treat various ailments (Ghebreselassie et al., 2011).

2.6 Anti-nutritional factors

Although soybean, moringa and OFSP are rich in many nutrients, they contain anti-nutritional compounds that have to be removed. Some of these chemicals are tannins and phytic acid, (Khattab and Arntfield, 2009).

2.6.1 Phytic acid

Phytic acid (dihydrogen phosphate) and phytate (salts of phytic acid) are widespread in plant seed grains (also including cereals), legumes, roots and tubers. Molecular formula of phytic acid is C_6H_6 [OPO (OH) $_2$] (Figure 2). Phytate accumulates in the seeds during the ripening period and is the main storage form of both phosphate and inositol in plant seeds and grains (Mohamed et al., 2011). One gram of soybean flour contains approximately 4 mg phytate, representing 57% of the total organic phosphorus (Kirby and Nelson, 1988). The mineral content of legumes like soybean is generally high, but the bioavailability is poor due to the presence of phytate, which is a main inhibitor of iron, calcium and zinc absorption. Phytate not only decreases the bioavailability of essential minerals, it also decreases the bioavailability of proteins by forming insoluble phytate-mineral and phytate-protien complexes (Tajoddin et al., 2011).

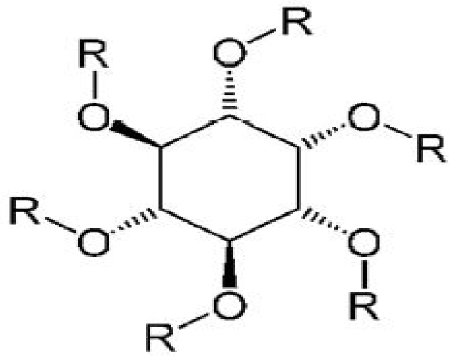


Figure 2. Chemical structure of phytic acid, Source; Ali et al., (2010).

2.6.2 Tannins

Food tannins are polyphenolic compounds that are widely distributed in plants. Tannins are predominantly located in the pericarp and/ or testa, particularly of pigmented cultivars of legumes and millets (Deshpande et al., 1982). They are readily form indigestible complexes with proteins and other macro-molecules under specific environmental conditions. Tannins are known to be present in food legumes and to inhibit the activities of trypsin, chemotrypsin, amylase and lipase, decrease the protein quality of foods and interfere with dietary iron absorption (De Lumen and Salamat, 1980). It has been reported that tannins affect protein digestibility and adversely influencing the bioavailability of non-haem iron leading to poor iron and calcium absorption. The carbohydrate is also affected by tannins leading to reduced energy value of a diet containing tannins (Adeparusi, 2001). The tannins have traditionally been divided into two groups: the condensed and the hydrolysable tannins (Figure 3). Hydrolysable tannins (HT) are made up of a carbohydrate core whose hydroxyl groups are esterifies with phenolic acids (mainly gallic and hexahydroxydiphenic acid). The condensed tannins (CT), or proanthocyanidins, are non-branched polymers of flavonoids units (flavan-3-ol, flavan-3, 4-diol), and usually have a higher molecular weight than the hydrolysable tannins (Frutos et al., 2004).

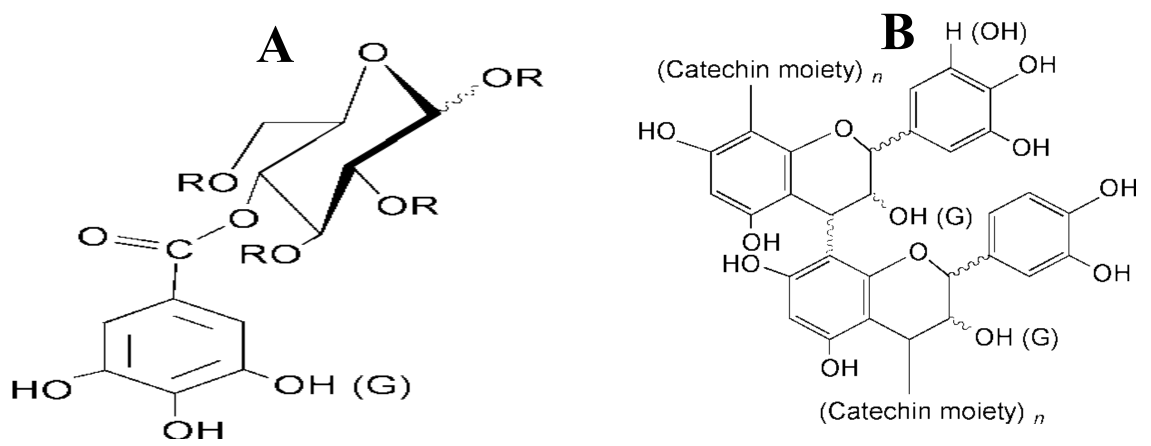


Figure 3. Chemical structures of (A) hydrolyzable tannin (gallotannin) and (B) condensed tannin. Source; Khanbabaee and Ree (2001).

2.7 Functional properties

Functional properties are the intrinsic physicochemical characteristics which may affect the behaviour of food systems during processing and storage. Adequate knowledge of these properties indicates the usefulness and acceptability for industrial and consumption purpose (Adeleke and Odedeji, 2010 and Islam et al., 2012). Different properties of flour such as water absorption capacity (WAC), bulk density, foaming capacity (FC) and foaming stability (FS) swelling capacity and viscosity predict the functional properties of products (Kanu et al., 2009).

2.7.1 Water absorption capacity (WAC)

The water absorption capacity is an index of the maximum amount of water that a food product would absorb and retain and also it represent the ability of the product to associate with water under conditions where water is limiting (Edema et al., 2005; Ojukwu et al., 2012). The high water absorption capacity of the flours suggests they could be useful in soup formulations and it gives an indication of the amount of water needed to form a gruel that results to gelatinization. Lower water absorption is desirable for making thinner gruels that will enhance more in-take of nutrients (Kanu et al., 2009).With respect to water absorption capacity, the microbial activities of food products with low water absorption capacity would be reduced (Ijarotimi and Keshinro, 2012).

2.7.2 Bulk density

Bulk density is a measure of heaviness of flour and in packaging (Appiah et al., 2011). The lower loose bulk density implies that less quantity of the food samples would be packaged in constant volume thereby ensuring an economical packaging. However, the packed bulk densities would ensure more quantities of the food samples being packaged, but less economical. Nutritionally, loose bulk density promotes easy digestibility of food products, particularly among children with immature digestive system (Ijarotimi and Keshinro, 2012). According to Nelson-Quartey et al. (2007), low bulk density flours are desirable in infant food preparation

2.7.3 Viscosity

Viscosity is considered an important attribute of foods because it affects mouth feel. The measurement viscosity of food product is much useful behavioral and predictive information to take guidelines in formulation, processing and product development (Shahnawaz and Shiekh, 2011). The high viscosity of gruel is due to the presence of starch and proteins which are predominant nutrients in cereals-grain, root and tubers and oil seeds. Starch in particular, absorbs water on cooking forming a gelatinous mass while proteins will denature and expose more hydrophilic sites that will take up more water. These mechanisms increase the viscosity of formulations that contain significant amounts of them (Kanu et al., 2009).

2.7.4 Water activity

Water activity (aw) is defined as the vapour pressure of water in a sample divided by that of pure water at the same temperature. Water activity describes the availability “free water” of in a food system and is related to the susceptibility of food to microbiological spoilage. (Bechoff, 2010). “Free water” refers to the water molecules in a sample that are not chemically or physically bound. Water activity is equivalent to Equilibrium Relative Humidity (ERH), which is the ratio of water vapor pressure above any sample to the water vapor pressure of pure water at the same temperature (Sostakiene and Blazgiene, 2010).

To generalize the above reviews, deficiencies of macro- and micro-nutrients are serious problems in Ethiopia. As it has been reported by several authors, vitamin A, protein and iron deficiencies are the most serious problems in pregnant and breast feeding mothers and their children. There are different opportunities to reduce these problems. Availability of cheap and locally accessible nutritionous crops such as OFSP, soybean and moringa is one of the opportunities to combat malnutrition, but little is known about the utilization and the type of their blended products. Hence, in this study nutrient rich product (porridge) was generated through blending of different proportions of OFSP, soybean and moringa leave powder for pregnant and breast feeding women to reduce the serious malnutrition challenge.

3. MATERIALS AND METHODS

3.1 Description of the experimental site

The experiment was conducted at Jimma University College of Agriculture and Veterinary Medicine (JUCAVM), Post-Harvest Management laboratory between 2011 and 2012. JUCAVM is located at south western part of Ethiopia at 346 kms south west away from Addis Ababa. Geographically, it is located at about $7^{o}33$"N latitude and 36.57^{0} E longitude with elevations of 1710 m.a.s.l The temperature and relative humidity in post harvest management laboratory during the conduction period of the experiment was in a range of 24-27^{0}C and 57-60% respectively.

3.2 Experimental materials

Crops used in this study were collected from different places. 200 Kg Orange fleshed sweet potato (OFSP) cultivar Tulla was obtained from Hawassa Agricultural Research Center. 30 Kg Soybean cultivar Clark 63K was provided by Jimma Agricultural Research Center. *Moringa stenoptala* leaves were collected from Alagae TVET College.

3.3 Sample preparation

The experimental samples were prepared following proper preparation methods prior to conducting the experiments. Preparations were made to convert orange fleshed sweet potato tuber, soybean grain and moringa leaves into powder forms. Every detail preparation procedures are depicted accordingly.

3.3.1 Preparation of OFSP flour

The processing of Orange fleshed sweet potato tubers in to flour was done by following the procedure of Hagenimana et al., (1999). OFSP tubers were thoroughly sorted to remove the one that has defects from the lot. The sorted tubers were washed in clean water in large buckets. It was cut into uniform pieces of about 3 mm thick to facilitate drying and ease milling operations. Sweet potato chips were evenly spread under sun drying for about 3-4 days. The dried chips were milled by using a miller (KARLKOLB D-6072 Dreich. West Germany) into flour and sieved through 0.5 mm sieve. Finally, it was packaged and sealed in high density polythene bag until it was ready for use. The general flow of OFSP tuber processing into flour is presented in Figure 4A.

3.3.2 Preparation of soybean flour

Soybean flour was prepared according to Famurewa and Raji (2011). It was started by separating the dirt, immature and odd types from the collected soybean. The unwashed soybean was poured into boiling water and boiled for 30 minutes. The boiled beans were removed from the fire and the water was poured out and then washed with cold water. The cooked beans were placed in a basin of fresh water and the beans was agitated between fingers to remove the hulls, and the water was pour off, the hulls were removed with the water. The drained soybean was oven dried (LEICESTER LE67 5FT, England) at a temperature of 60°C for 13 h to a constant weight. Finally, the dried cooked soybean was grinded in a grinding mill (KARLKOLB D-6072 Dreich. West Germany) followed by sieving (0.5mm) the ground beans to produce finer flour. The soybean powder was stored in an air-tight container until the end usage. The general flow of soybean seeds processing into flour is presented in Figure 4B.

3.3.3 Preparation of moringa leaves powder

The Moringa leaflets were stripped from the leaf petiole followed by discarding diseased and damaged leaves. The leaflets were washed by using clean potable water to remove dirt and drained for 5 minutes. Then, leaves were dried at room temperature. The dried leaves were milled by using a mill (KARLKOLB D-6072 Dreich. West Germany) prior to sieving the leaf powder using 0.5mm sieves. The general flow for moringa leaves processing into powder is presented in Figure 4C.

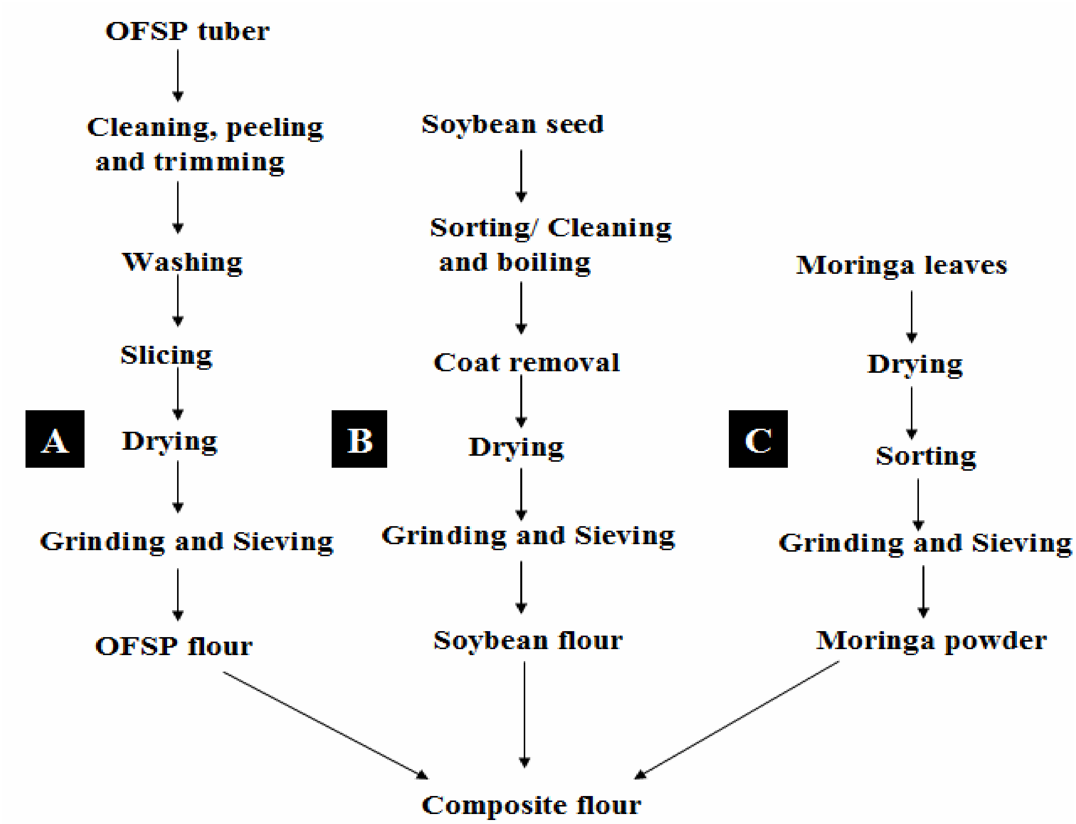


Figure 4. Schematic presentation of experimental sample materials processing and formation of composite flour. A) Orange fleshed sweet potato tuber processing, B) soybean seed processing and C) Moringa leaf processing.

3.4 Experimental design and blend formulation

The composite flour was formulated by blending of three crops using D-optimal mixture design. The mixed products were obtained by inserting high and low levels of orange fleshed sweet potato, soybean and moringa (Table 7). The Flour blends containing these three components with different proportion were mixed using a blender for 2-3 min (Table 8). Finally, the samples were packed and sealed in high density polyethylene bags.

Table 7. Food components and levels selected to prepare the mixture design of food fortification.

Mixtures components	Levels (%)	
	Low	High
OFSP	60	85
Soybean	10	30
Moringa	5	10

Table 8. Different Proportions of components in preparation of composite flour

Run	**Mixtures Components (%)**		
	OFSP	**Soybean**	**Moringa**
1	76	19	5
2	80	15	5
3	80	15	5
4	69	26	5
5	64.5	30	5.5
6	72	21	7
7	72	21	7
8	72	21	7
9	72	21	7
10	82.5	10	7.5
11	82.5	10	7.5
12	64.4	26.2	9.4
13	60.5	30	9.5
14	78	12	10
15	75	15	10
16	68	22	10

3.5 Preparation of gruel

Gruel was prepared from the fortified products. First, 870 ml water was boiled prior to adding 1.5 g salt and 300 g of blended flour was added to it. The mixture was stirred until the gruel is getting gelatinous for 20 min. Afterwards, chemical, physical and sensory evaluation data were collected using samples according to every analysis procedures.

3.6 Methods of analysis and data collection

Data were collected on such as; proximate composition, total carotenoid content, and minerals content, functional properties, anti-nutritional factors content and sensory evaluation of composite gruel. The analysis and data collected were conducted in Ethiopian Health and Nutrition Research Institute (EHNRI), Food and Nutrition Research Department, Addis Ababa, Ethiopia, JUCAVM Post-Harvest laboratory and Jimma University, Chemistry Department laboratory. The separate analysis and determination procedures for every parameter are described below accordingly.

3.6.1 Proximate composition analysis

Determination of moisture content: the moisture contents of the experimental samples were determined according to AOAC (2000) method 925.09. The empty dish and lid was dried in the oven for 15 min and then transferred in to desiccator for cooling, before it was weighed to the nearest mg. About 5g of the sample was transferred to the dish and then the dish was placed in the oven (LEICESTER LE67 5FT, England) at 102^{O}C for 6h and cooled in desiccators and re-weighed. Then, the moisture content was estimated by the formula:-

$$\text{Moisture (\%)} = \frac{M2 - M1}{\text{M2}} X100 \qquad \text{…………………..Equation (1)}$$

Where;

M1= Weight of sample after drying; M2= Weight of fresh sample and dish

Determination of dietary (crude) fiber: the crude fiber in food samples was determined by following AOAC (2000) methods 920.09 procedures. About 1.5g weighed sample was transferred into a 600 ml beaker and about 200 ml 1.25% sulfuric acid was added before boiling for 30 minutes. After 30 minutes heating by gently keeping the level constant with distilled water, 20 ml KOH (28%) was added following gentle boiling for further 30 minutes. Subsequently, washing was made with 1% sulfuric acid and NaOH solution. Then, filtered and dried in air draft drought oven (memmert 854 Schwabach, West Germany) at 130^{0}C for 2 hours. Furthermore, it was cooled at room temperature for 30 minutes in a desiccator and weighed, then transferred it to crucible to muffle furnace (GALLENKAMP, Model FSL 340-0100, UK) for 30 minute ashing at 550 ^{0}C. Finally, it was cooled again in a desiccator and re-weighed. The crude fiber content was determined by using the following formula:

$$\text{Crude fiber (\%)} = \frac{M1 - M2}{\text{Weight of sample}} x100\% \qquad \text{……………..Equation (2)}$$

Where, M1= Weight of crucible and residue

M2= Weight of crucible and ash

Crude protein analysis: the crude protein content was analyzed by *micro-Kjeldahl* method of nitrogen analysis according to AOAC (2000) method 979.09. To a digestion flask containing about 0.5 g of sample, 6 ml of acid mixture (conc. sulphuric acid and conc. orthophosphuric acid) and about 3g of catalyst mixture (K_2SO_4 and Selenium) were added and digested (Kjeldahl flask KF250, Technical Glass Products, Inc., USA) at about 370^{0}C until the solution becomes clear. To the digested sample, distilled water (30mL) was added and then, ammonia was distilled off after adding 25 ml of NaOH (40%) into receiving flask (25 ml of boric acid with 10 drops of indicator solution). Finally, the distillate was titrated with standardized 0.1N sulfuric acid to a reddish color. The crude protein content was estimated using the formula:

$$\text{Total nitrogen percent by weight} \quad \%N = \frac{(T - B) * N * 14.007 * 100}{\text{W}} \qquad \text{…………Equation (3)}$$

Where, T: Volume in ml of the standard sulfuric acid solution used in the titration for the test material

B: Volume in ml of the standard acid solution used in the titration for the blank determination

N: Normality of standard sulfuric acid

W: Weight in grams of the test material

*Crude protein, percent per weight = 6.25 * total nitrogen*

Crude fat content determination: crude fat content was determined by Soxhlet fat extraction according to AOAC (2000) method 4.5.01. A clean and dried thimble containing about 3.5 g of dried sample and covered with fat free cotton at the bottom and top was placed in the extraction chamber. The beaker was rinsed for several times with the solvent hexane. The sample contained in the thimble was extracted with the solvent hexane in a Soxhlet extraction apparatus (SZC-C fat determinate, China) for 6-8 hrs at a condensation rate of at least 3-6 drops per second. At the completion of the extraction, the extracted was transferred from the extraction flask into a pre-weighed evaporating small beaker (150-250 ml) with several rinsing with the solvent. The hexane was evaporated until no odor is detected. The beaker and contents was dried in an oven for 30 minutes at 100^0C followed by cooling in desiccators. Finally, the beaker and contents was weighed and the crude fat content was determined using the following formula:

Weight of fat (W_f) = $W_a - W_b$

where, W_a = *weight of extraction flask after extraction*

W_b = *weight of extraction flask before extraction*

$$\textit{Crude fat content (\%)} = \frac{Wf * 100}{SW} \qquad \text{………………………Equation (4)}$$

Where, SW = weight of samples

Total ash determination: the ash content was determined by AOAC (2000) method 923. A porcelain dish was placed in muffle furnace for 15 minutes prior to cooling in desiccators for an hour. The mass of dried porcelain dish was measured by analytical balance (M1). A dry porcelain dish containing 5g sample was weighed (M2) and placed in a muffle furnace (Model SX-5-12, China) set at 550^0C overnight. The sample was removed from the furnace and placed in the desiccators followed by weighing the mass (M3).

$$\text{Ash (\%)} = \frac{M3 - M1}{\text{M2 - M1}} * 100\% \qquad \text{…………………………Equation (5)}$$

Where; M1= Weight of the dish

M2= Weight of fresh sample and dish; M3= Weight of ash and dish

Crude carbohydrate determination: carbohydrate content was determined by subtraction of the above tested parameters from 100%.

3.6.2 Total carotenoids analysis

Total carotenoid of the product was determined according to the method of Gross, (1991). About 5 g of homogenate sample was taken to be analyzed and then it was extracted with 30 mL of acetone/ethanol (50:50) solution. The homogenate extract was filtered under suction in a Buchner funnel and was washed with acetone/ethanol solvent until it becomes colorless. The filtrate volume was adjusted to 100 ml with acetone/ethanol before the aliquot of total carotenoid solution was filled in a clean cuvette or glass used for sample holding in Uv-Vis spectrophotometer (Series UV/Vis spectrophotometer PG. instrument Ltd., T80, China) analysis (1cm thickness). The absorbance was read at 470nm. The total carotenoid content was determined by using equation given below:

$$\text{Total carotenoids per sample } (\mu g/g) = \frac{AxVx10^6}{A1cm^{1\%}x100xG} \quad \text{……………..Equation (6)}$$

Where: A = absorbance at 470 nm; V = total volume of solution; G = gram of sample; and A1cm1% = specific extinction coefficient at 470 nm = 2,500

3.6.3 Determination of minerals (Ca, Fe and Zn) contents

The contents of Ca, Zn and Fe in foods were measured by atomic absorption spectrophotometer (AAS) (Perkin-Elmer, Model 3100, USA) according to the method of Hernandez *et al.* (2004) after dry ashing of about 5g sample. The resulting white ash was weighed, dissolved in 3ml of concentrated nitric acid and then finally diluted with distilled water in a 25ml calibrated flask. Then the solution was used to determine Ca, Zn, and Fe. Standard stock solution of iron, zinc and calcium was made by appropriate dilution. The sample and standard was atomized by using air –acetylene as a source of energy for atomization (AACC, 2000). For iron content determination absorbance was measured at 248.3nm and iron was estimated from a standard calibration curve prepared from analytical grade iron wire with a range of 0, 0.05,2,4,8 and 16ml. For zinc content determination, absorbance was measured at 213.8nm and zinc level was estimated from a standard calibration curve prepared from ZnO. For calcium content determination, absorbance was measured at 422.7nm after addition of 1% lanthanum (i.e., 1mL La solution/5mL) to sample and standard to suppress interferences. Calcium content was then estimated from standard solution 0, 0.05, 2, 4, 8 and 16 ml prepared from $CaCO_3$.

3.6.4 Determination of anti-nutritional factors

Condensed tannin determination: Modified procedure (Maxson and Rooney, 1972) was used for condensed tannin. About 1g of weighed sample was extracted with 10ml of 1% HCl in methanol for 24 hrs at room temperature with mechanical shaking after centrifugation at 1000 rpm for 5min then 1ml of the supernatant was mixed with 5ml of vanillin HCl reagent which was prepared by combining equal volume of 8% concentrated HCl in methanol and 4% vanillin in methanol. Finally, absorbance was read at 500 nm after 20 min using UV-Vis Spectrophotometer (DU-64 spectrophotometer, Beckman, USA). A stock catechin solution was used as the standard (20 mg catechin dissolved in 100ml 1% HCl in methanol) and value of tannin was expressed in mg of catechin / gm of sample. Calibration curve was constructed by using a series of 0, 12, 24, 36, 48 and 60 ml stock solution diluted to 25ml of 1% HCl in methanol.

$$\text{Tannin (mg/100g)} = \frac{(A_s - A_b) - Intercept}{\text{Slope} * \text{d} * \text{W}} \quad \text{……………………Equation (7)}$$

Where, A_s=sample absorbance; A_b= blank absorbance

d=density of solution (0.791g/ml); W= Weight of sample in gram

Determination of phytate: Phytate was determined by using modified procedure of Vaintraub and Lapteva (1988). About 5 g of dried sample was extracted with 100 ml 2.4 % HCl for an hour at an ambient temperature and centrifuged at 3000 rpm for 30 min. The clear supernatant was collected and 3ml of sample solution was mixed with 1ml of wade reagent (0.03 % solution of $FeCl_3.6H_2O$ containing 0.3% sulfosalicylic acid in water) followed by centrifugation. The absorbance at 500 nm was measured using UV-Vis Spectrophotometer (DU-64 spectrophotometer, Beckman, USA). Absorbance of standard phytic acid solution was measured as for the sample after reacting with wade reagent (3ml of water + 1ml of wade reagent). The phytate content of the food sample was estimated from the calibration line and expressed as phytic acid in mg/100g weight of sample.

$$\text{Phytic acid in } \mu\text{g/g} = \frac{Abso - Intercept}{\text{Slope} * \text{density} * \text{wt.sample}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\text{Equation (8)}$$

Abso =absorption; Density=density of the solvent

3.6.5 Determination of functional properties

Water absorption capacity: It was determined following Beuhat (1977) method. Sample (1g) was mixed with 10ml of distilled water for 30 seconds in a vortex mix (set on fast speed). The samples were allowed to stand at room temperature ($21^{O}C$) for 30 minutes, centrifuged at 5000 rpm for 30 minutes and the volume of the supernatant was measured in a 10 ml graduated cylinder.

$$WAC(ml) = 10ml - X \text{ , } \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{ Equation (9)}$$

Where, X= final reading from the cylinder

Bulk density: Bulk density was determined by the method of Narayana and Narasinga (1984). A specified quantity of the flour sample was transferred into an already weighed measuring cylinder (W_1). For the packed bulk density determination, the flour sample was gently tapped to eliminate spaces between the flour and the level was noted to be the volume of the sample and then weighed (W_2). No tapping was made in the case of loosed bulk density and the level was also noted to be the volume of the sample and then weighed.

$$BD(g/ml) = \frac{W2 - W1}{Y} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{ Equation (10)}$$

Where, BD= Bulk density; W2= sample + cylinder weight;
W1= cylinder weight; Y= volume of sample

Viscosity: The viscosity of product was determined with a Thermo haake falling ball (sphere) viscometer (D-76227, Germany). A 10% slurry (dry matter basis) of each sample was prepared with 200 ml distilled water followed by uniform heating prior to cooling to 21 to 25°C for 15 min. Approximately 40 ml of sample was poured into the measuring tube before introducing the ball into the tube. The ball was run through the liquid between 2 ring marks without measurement primarily. Then, it was run again and the time required to finish rolling speed of the ball from upper to lower ring mark was measured. To be more precise, the test was run 3 times. Finally, the dynamic viscosity (η) in millipascal seconds was calculated using the formula:

$$\eta = \kappa(\rho 1 - \rho 2) \times t \qquad \text{……………………Equation (11)}$$

k = constant, expressed in millimeter squared per second squared,

ρ_1 = density of the ball used, expressed in grams per cubic centimeter,

ρ_2 = density of the liquid to be examined, expressed in grams per cubic centimeter

t = falling time of the ball, in seconds.

Water activity: the water activity of the sample was determined by LabMaster-a_w instrument. A homogenous flour sample was placed in a sample cup, completely covering the bottom of the cup. The sample of flour was half filled in the cup because of the overfilled cups might contaminate the sensors in the sensor chamber. The sample drawer knob turned to the OPEN/LOAD position and pull the drawer open. Then, prepared sample was placed in the drawer followed by carefully closing of slide the drawer. Prior to starting cycle reading, the sample drawer knob was turned to the READ position to seal the sample cup with the chamber. The first water activity was measured during about 8-10 min.

3.6.6 Sensory quality evaluation of the gruel

Both untrained and semi-trained sensory panel of 50 members was organized consisting of staff and graduate students from Jimma University College of Agriculture and Veterinary Medicine. Coded cups (with random 3-digit numbers for identification) with samples of thin porridge were arranged horizontally on the table. Then, panelists were asked to evaluate color, odor, taste, consistency and over all acceptability of the product by using five point hedonic scales (from “5” – like very much, to “1” - dislike very much). The scores were recorded on score card sheet provided by moving one sample to other after washing their mouths with water. Finally, the score of all judges for each sample were summed up and divided by the number of panelists to find the average score.

3.7 Statistical analysis

A statistical software package (Design-Expert ®, version 8.0, Stat-Ease) was used for the generation of test formulation and MINITAB, version 16, software package was used for data analysis, construction of contour plot, response surface plot and overlaid plot of the results. These formulations were obtained based on a constrained mixture D-optimal design in both softwares. The statistical significance of the terms in the regression equations was examined by analysis of variance (ANOVA) for each response and the significance test level was set at 5% ($P < 0.05$). The fitted models for all the parameters were generated in three-dimensional response surfaces and contour plots. Graphical optimization was carried out to determine the optimum formulation point of OFSP, soybean and moringa porridge making for chemical compositions (protein, total carotene and iron) and sensory attribute (overall acceptance).

4. RESULTS AND DISCUSSION

In this chapter data collected on proximate compositions (moisture, ash content, protein, crude fiber, fat, and carbohydrate), minerals (Fe, Ca and Zn), total carotenoid and anti-nutritional factors (phytate and tannin), functional properties (water absorption capacity, bulk density, water activity and viscosity) and sensory attributes are described, presented in different tables/ figures and discussed.

4.1 Proximate composition

The proximate compositions of individual ingredients (OFSP, soybean and moringa) were analyzed prior to analysis of the proximate compositions of gruel. Mean values of moisture content, total ash, crude fat, crude protein, crude fiber and carbohydrate contents of the gruel and individual ingredients are summarized in Table 9. The mean minimum and maximum values obtained from these different mixed products ranges from 2.12-6.10%, 4.45-4.86%, 1.92 - 8.22%, 12.44 - 19.49%, 3.15 – 4.80%, and 58.47-70.70% for moisture, total ash, crude fat, crude protein, crude fiber and carbohydrate contents respectively. Analysis of variance results are summarized in Appendix A. The composition of protein, ash and crude fiber in composite samples were significantly affected ($p<0.05$) by OFSP, soybean and moringa and/or their levels in both linear and quadratic models, while other proximate compositions were not significantly different. The experimental results R^2 values indicated that the models were satisfactory and it did not have lack of fit ($p > 0.05$) (Appendix A).

Table 9. Proximate compositions of the blended (mixed) products.

Mixture Composition %)			Proximate compositions (%)					
OFSP	**Soybean**	**Moringa**	**MC**	**PC**	**FaC**	**AC**	**FiC**	**CC**
76	19	5	3.59	14.78	4.37	4.50	3.58	69.18
80	15	5	4.64	13.53	3.84	4.47	3.53	69.99
80	15	5	4.59	13.40	6.07	4.48	3.15	68.31
69	26	5	3.30	17.33	7.00	4.50	3.63	64.24
64.5	30	5.5	2.12	18.76	8.06	4.58	4.31	62.17
72	21	7	3.60	16.15	5.35	4.53	4.02	66.35
72	21	7	2.60	16.39	5.63	4.53	4.06	66.79
72	21	7	3.08	16.31	5.66	4.45	3.73	66.77
72	21	7	5.12	16.19	5.06	4.54	4.01	65.08
82.5	10	7.5	5.87	12.44	2.28	4.64	4.15	70.62
82.5	10	7.5	6.10	12.53	1.92	4.57	4.18	70.70
64.4	26.2	9.4	4.13	18.44	5.83	4.69	4.47	62.44
60.5	30	9.5	4.16	19.49	8.22	4.86	4.80	58.47
78	12	10	4.85	13.26	3.09	4.70	4.29	69.81
75	15	10	5.74	14.54	2.82	4.72	4.35	67.83
68	22	10	4.53	17.21	5.13	4.73	4.35	64.05
100	-	-	NA	7.78	0.88	3.98	3.31	NA
-	100	-	NA	45.83	27.84	3.58	7.44	NA
-	-	100	NA	21.04	5.36	9.79	13.01	NA

OFSP = 60-85%, Soybean = 10-30% and Moringa = 5-10%; MC= moisture content; PC= protein content; FaC= fat content; AC= ash content; FiC= crude fiber content; CC= carbohydrate content; NA = Not analyzed.

The moisture content of porridge (gruel) was not significantly different. The highest (6.10%) and lowest (2.12%) moisture content of gruel were recorded for mixture ratio of 82.5:10:7.5% and 64.5:30:5.5% of OFSP, soybean and moringa, respectively. The lowest content of moisture is known to help to increase the concentration of nutrients and can make them more available in the product (Aprianita et al., 2009).

The porridge of OFSP supplemented with 30% soybean flour had the highest crude protein content of 19.49 %. Increase in protein content across increased proportion of soybean flour in the product was due to the high protein content in soybean flour (IITA, 1990; Fabiyi, 2006). The high protein content in the OFSP products enriched with soybean would be of nutritional importance in most developing countries like Ethiopia where many people can hardly afford high protein foods because of their high cost. This similar observation was made in research study by Sanful et al. (2010) and Ndife (2011) who showed an increase in the protein content with corresponding increase in the proportion of soy flour supplementation in wheat flour during the production of cake (from 6.8 to 9.3%) and bread (8.13 to 12.50%) respectively. A research done by Jimoh and Olatidoye (2009) also showed that as the proportion of soybean flour increased from 0 to 30 % in product development containing yam increased the protein content from 3.2 - 18.2%.

Apart from soybean, porridge enriched with protein might be strengthened by moringa flour since moringa flour consists of high amount of protein (Dolcas, 2008; Moyo et al., 2011; Yameogo et al., 2011). Thus, OFSP complemented with soybean and moringa with different levels produced protein enriched porridge (gruel) may be used to alleviate macronutrient malnutrition in pregnant and breast feeding women. Figure 5 (contour graph of protein contents from different formulations) showed that increasing the proportion of soybean in the formulation to its maximum level, increased the amount of protein in the thin porridge.

Regression model for protein:

$Y = 4.3X_1 + 27.7X_2 -368.4\, X_3 +18\, X_1X_2 + 462.6X_1X_3 + 486.4X_2X_3$ ………...Equation (12)

Where, X_1 = OFSP; X_2 = Soybean; X_3 = Moringa; R^2= 99.79

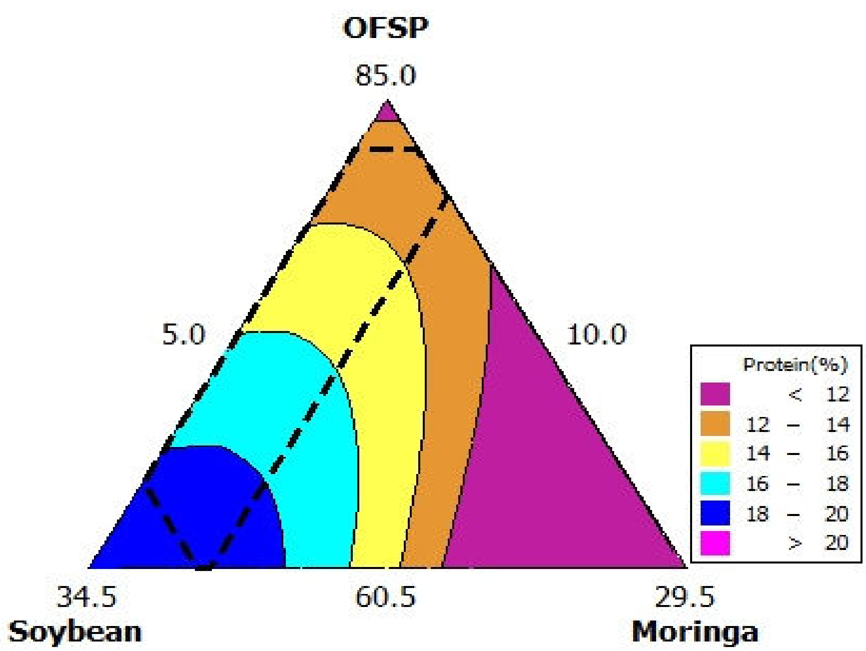


Figure 5. Contour plot for protein contents (%) of the formulations.

The high ash content of food items is a reflection of the mineral contents preserved in the food materials (Oduro et al., 2008). As can be referred from Table 9, the total ash content of the formulated porridges has increased as the ratio of moringa and somehow soybean flour increased from 5-10 % and 10-30 % respectively in the mixtures (Figure 6). This was due to the high content of ash in moringa and soybean flour. Similar trends were reported by Ndife et al. (2011) and Olatidoye and Sobowale (2011) on soybean and Dachana et al., (2010) on moringa. The results, therefore, suggest a high deposit of mineral elements in moringa leaves.

Regression model for Ash;

$Y = 5.22X_1 + 10.98X_2 + 82.34\,X_3 - 10.7\,X_1X_2 - 88.26X_1X_3 - 85.25X_2X_3$ …………Equation (13)
Where, X_1 = OFSP; X_2 = Soybean; X_3 = Moringa; R^2= 93.69

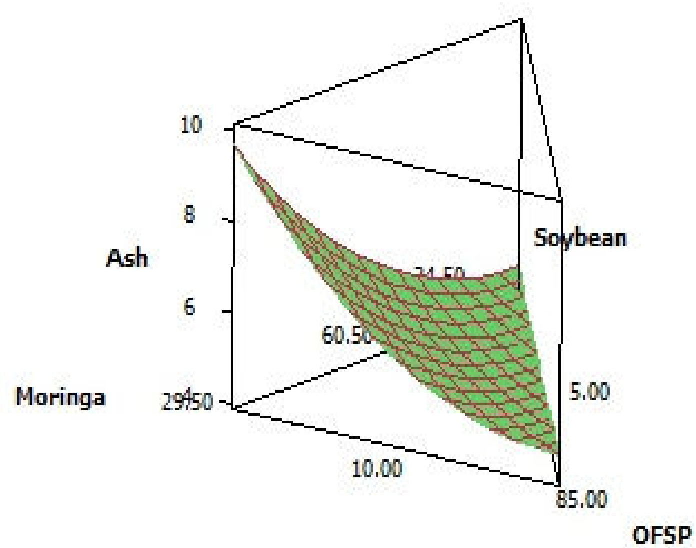


Figure 6. Response surface plot of ash content (%) of the formulations.

Addition of moringa and soybean flour in the formulation shows an increasing trend of crude fiber contents (Figure 7), suggesting moringa is a good source of crude fiber. This could be due to the high amount of crude fiber in moringa leaves. This result was in agreement with the work of Abuye et al. (2003), Mellesse et al. (2008; 2011), Yameogo et al. (2011) and Oduro et al. (2008). Ndife et al. (2011) reported that dietary fibre plays a significant role in the prevention of several diseases such as; cardiovascular diseases, constipation, irritable colon, cancer and diabetes. A number of studies have also indicated that components of plants such as dietary fiber have beneficial effects in lowering blood cholesterol levels aside from the decreased intake of saturated fat and cholesterol that occurs with high intakes of plant foods (Ekumankama, 2008).

Regression model for crude fiber;

$Y = 1.9X_1 + 27.7X_2 - 205X_3 - 35X_1X_2 + 268.7X_1X_3 + 207.9X_2X_3$ ....Equation (14)

Where, X_1 = OFSP; X_2 = Soybean; X_3 = Moringa; R^2 = 92.22

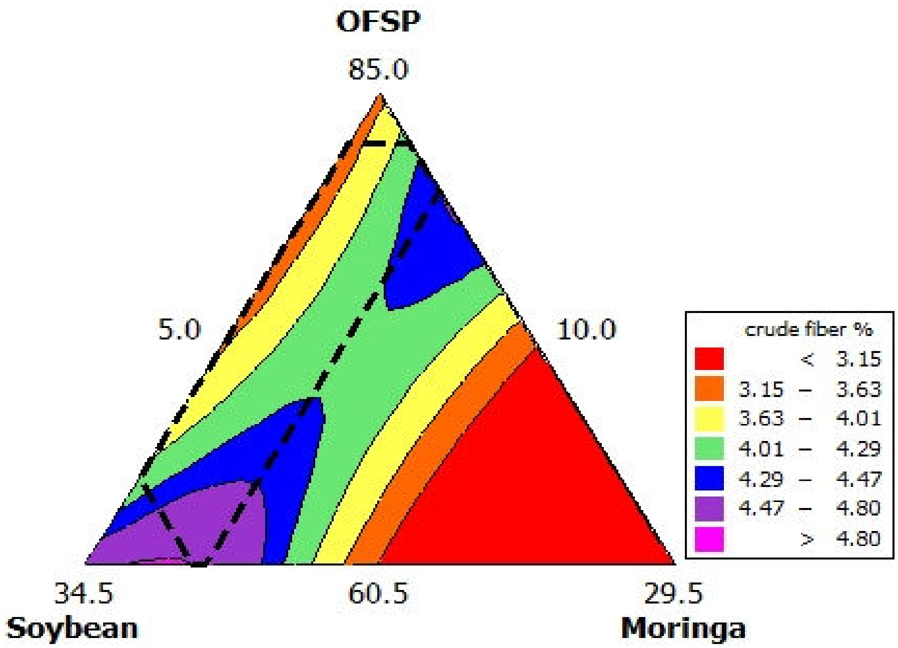


Figure 7. Contour plot of crude fibre (%) of the formulations.

The crude fat and carbohydrate content of the samples were not affected significantly by the proportion of components. However, the results showed a trend of increases in the amount of these nutrients when the proportion of soybean and OFSP increased in the mixtures. Soybean seeds have been reported to contain appreciable amount of fat (Olatidoye and Sobowale, 2011; Masur et al., 2009). According to Sanful et al. (2010), addition of soybean flour increases the content of fat in fortified cake while the amount of carbohydrate is reduced. The content of carbohydrate increased when the proportions of OFSP increased also reported by (Faber et al., 2010) and to some extent with the increment of moringa proportions (Yisehak et al., 2011).

4.2 Total carotenoid content

The total carotenoid contents of unmixed OFSP, soybean and moringa flours were measured to quantify the carotenoid contents in the source materials. ANOVA and p-values for total carotenoid content are summarized in Appendix A. Total carotenoid content of gruel was not significantly different in both linear and quadratic models. As the R^2 values indicated, the models were satisfactory and good fitting (lack-of-fit, P> 0.05) to experimental results (Appendix A). Total carotenoids measured from the three individual flour samples and their mixture products had ranged from 1341.93 -2057.32 µg/100g (Table 10). The results indicated that total carotenoid content increased as the proportions of OFSP and moringa flour increased in the formulations.

An increased total carotenoid content in this work was observed for porridge /gruel prepared from higher proportions of moringa and OFSP (Figure 8). It has been reported that OFSP is rich in *β*-carotene since 90% of total carotenoid is *β*-carotene, the precursor of vitamin A (Bechoff, 2010). The increase in the total carotenoid (*β*-carotene) content in line with the increasing proportion of OFSP proportion is in agreement with previous works reported by Jaarsveld et al. (2005), who assessed the efficacy of daily consumption of boiled and mashed OFSP in improving the vitamin A status of primary school children.

It has been reported that an increase in β-carotene content corresponding with increase in the proportion of orange-fleshed sweet potato supplementation in products (Woolfe, 1992; Low and Jaarsveld, 2008 and Amagloh et al., 2011). Supplement of moringa has also improved the total carotenoid contents of the products because it can act as an alternative source of vitamin A precursor, *β*-carotene (Dachana et al., 2010). Hence, one approach to increase food availability and tackling vitamin A deficiency would be to utilize orange-fleshed sweet potato (OFSP) (Low et al., 1997) and moringa (Dolcas, 2008) through enrichment technique.

Regression model for total carotenoid;

$Y = 2405X_1 + 1874X_2 + 62399X_3 - 3074X_1X_2 - 66419\,X_1X_3 - 76629\,X_2X_3$ ....Equation (15)
Where, X_1 = OFSP; X_2 = Soybean; X_3 = Moringa; R^2 = 90.99

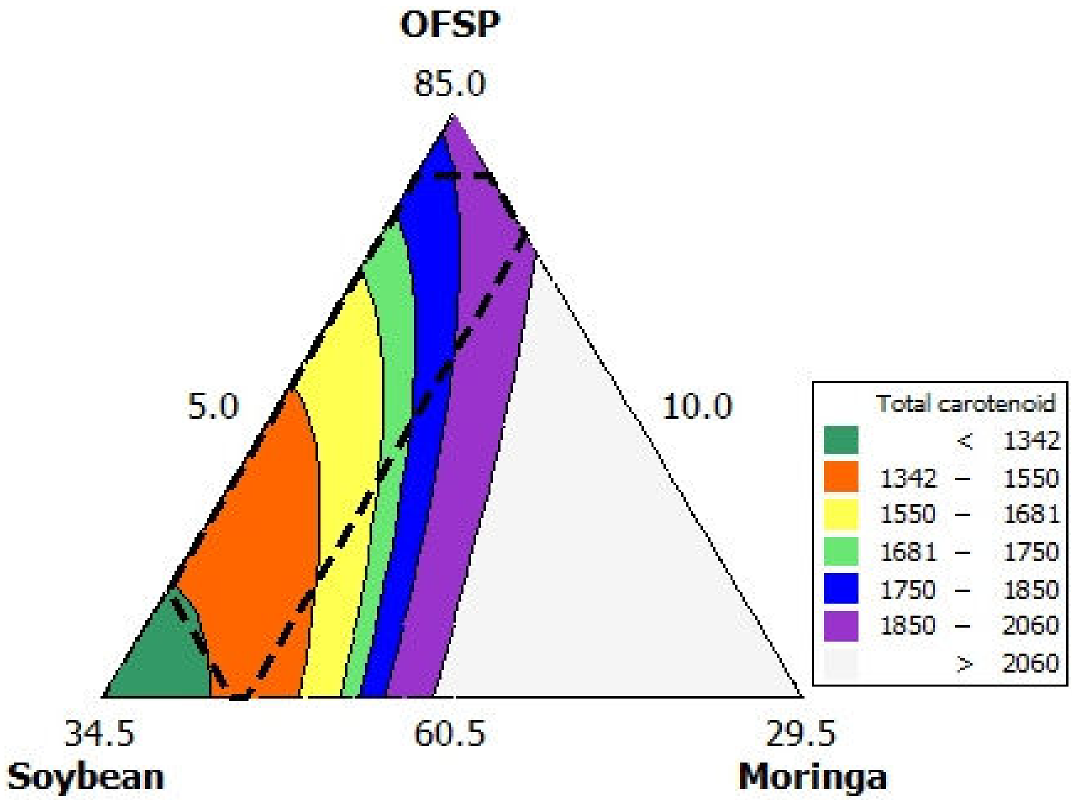


Figure 8. Contour plot of total carotenoid contents (µg/100g) of the formulations.

Table 10. Total carotenoid and mineral (Fe, Ca and Zn) contents of the product.

Mixture Compositions (%)			Total Carotenoid (µg/100g)	Minerals contents (mg/100g)		
OFSP	Soybean	Moringa		Fe	Ca	Zn
76	19	5	1555.66	17.49	27.10	BDL
80	15	5	1750.43	17.14	21.77	BDL
80	15	5	1771.41	16.92	25.96	BDL
69	26	5	1402.00	18.29	27.49	BDL
64.5	30	5.5	1341.98	18.38	28.50	BDL
72	21	7	1571.56	17.53	28.69	BDL
72	21	7	1680.67	17.54	27.88	BDL
72	21	7	1550.28	17.50	29.05	BDL
72	21	7	1520.98	17.54	28.84	BDL
82.5	10	7.5	1850.60	18.80	37.72	BDL
82.5	10	7.5	1917.49	19.95	41.00	BDL
64.4	26.2	9.4	1558.85	20.23	47.37	BDL
60.5	30	9.5	1351.25	21.58	49.40	BDL
78	12	10	2057.32	19.96	50.42	BDL
75	15	10	1755.25	20.27	49.92	BDL
68	22	10	1588.30	20.50	52.95	BDL
100	-	-	3861.16	7.44	78	BDL
-	100	-	NA	8.31	196.61	6.57
-	-	100	3168.27	55.02	647	3.2

BDL = Below Detection Level; NA = not analyzed.

4.3 Mineral contents

Mineral contents of individual components and their formulations were analyzed and presented in Table 10. The iron and calcium contents of the gruel range between 16.92 – 21.58 mg/100g and 21.77 – 52.95 mg/100g, respectively. The composition of Fe and Ca increased as the proportion of soybean and moringa flour proportions increased in the formulations (Table 10). The Zn content appeared below the detection levels (Table 10). The influence of each component (OFSP, soybean and moringa) in mineral content of final product were analyzed using ANOVA and p-values for models and interaction of individual components are summarized in Appendix A. The compositions of Fe and Ca in the product were significantly ($p<0.05$) influenced by OFSP, soybean and moringa proportions in both the linear and quadratic models. The R^2 values for Fe and Ca results showed that the models were satisfactory and good fitting (lack-of-fit, $p > 0.05$) to experimental results (Appendix A).

An increased Fe content was obtained in the porridge (gruel) when the proportion of moringa flour increased (Figure 9), suggesting moringa contributes to the iron content and used as a major source of iron (Abuye et al., 2003; Dolcas, 2008 and Melesse et al., 2011). Iron, which is commonly deficient in many plant-based diets, was found in abundance in this plant's leaves. Iron is a necessary component of haemoglobin and myoglobin for oxygen transport and cellular processes of growth and division (Moyo et al., 2011). Iron is also an essential trace element for normal functioning of the central nervous system and in the oxidation of carbohydrates, proteins and fats (Ogbe and Affiku, 2011). Iron also has a role in energy metabolism as it facilitates transfer of electrons in the electron transport chain for the formation of ATP (Moyo et al., 2011).

Regression model for Iron;

$Y = 26X_1 + 114X_2 + 956X_3 - 153\,X_1X_2 - 1050\,X_1X_3 - 1096\,X_2X_3$ ……………………Equation (16)

Where, X_1 = OFSP; X_2 = Soybean; X_3 = Moringa; R^2= 92.60

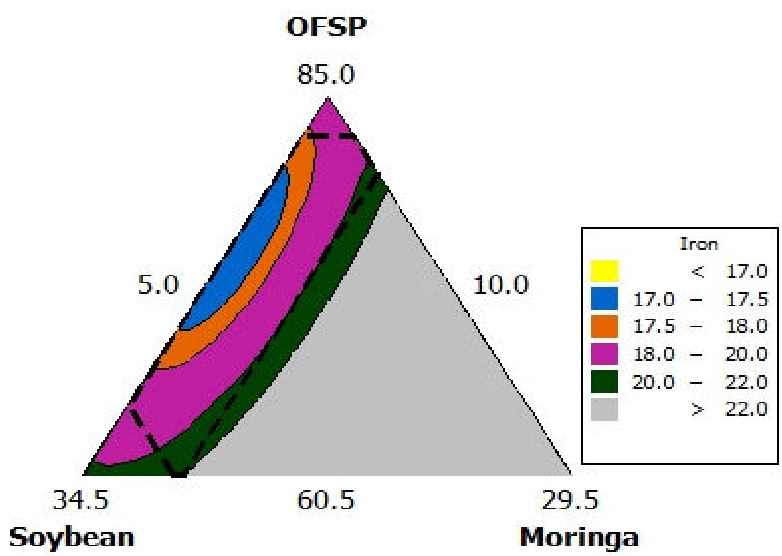


Figure 9. Contour plot of iron content (mg/100g) of the formulations.

Increased proportions of all ingredients are associated with elevated Ca content of gruel samples (Figure 10). Studies have showen that high content of Ca in OFSP (Faber et al., (2010), soybean (Masur et al., 2009) as well as moringa flours (Melesse et al., 2011). Calcium is required for formation and maintenance of bones and teeth thus, preventing osteoporosis in old age. It is also needed for normal blood clotting and nervous function (Moyo et al., 2011).

The content of Zn in the formulated products was found below the detection limit, suggesting the products contained low amount of zinc. The lowest zinc content in formulated porridge could be due to limited Zn content in OFSP (Esther and Ignitiatus, 2010) and moringa (Melesse et al., 2011). Besides, undetectable zinc content observed in the products may be in part contributed by processing and preparation losses (Sandstrom, 1989). Zinc is essential for the synthesis of DNA, RNA, insulin and function and/or structure of several enzymes. Zinc is also known for its anti-viral, antibacterial, anti-fungal and anti-cancer properties (Moyo et al., 2011).

Regression model for calcium

$Y = 64X_1 + 366X_2 + 7290X_3 - 540X_1X_2 - 7960X_1X_3 - 8250X_2X_3$ ....Equation (17)

Where, X_1 = OFSP; X_2 = Soybean; X_3 = Moringa; R^2= 96.32

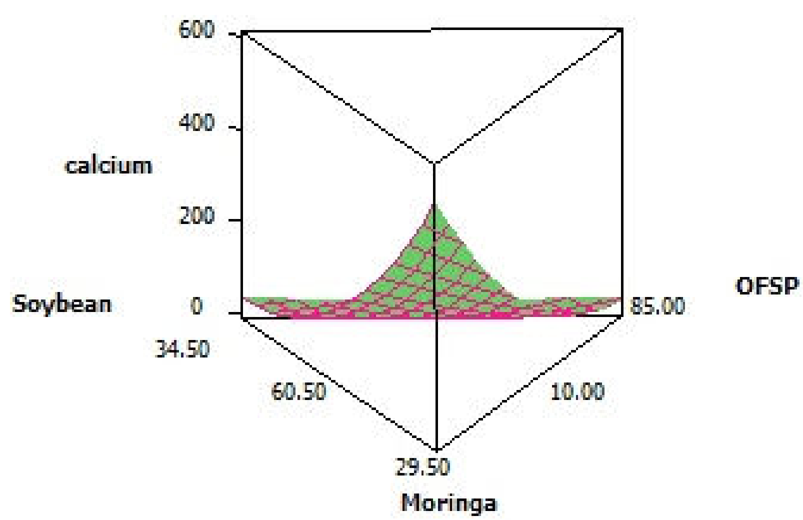


Figure 10. Contour plot of calcium content (mg/100g) of the formulations.

4.4 Anti-nutritional factors

Tannin and phytate contents of the formulations are summarized in Table 11. The content of tannin in gruels was significantly affected by proportion of individual components of the mixture in both linear ($p<0.01$) and quadratic ($p<0.05$) models, which were satisfactory and good fitting (lack-of-fit, $P>0.05$) to experimental results (Appendices A). An increased tannin content ranging from 65.64 – 98.54 mg/100g was measured for products whose proportion of moringa is increased from 5-10% in the mixture (Figure 11).

Table 11. Anti-nutritional factors of the formulations.

Mixture compositions (%)			Anti-nutritional factors (mg/100g)	
OFSP	**Soybean**	**Moringa**	**Tannin**	**Phytate**
76	19	5	65.64	106.01
80	15	5	68.87	102.47
80	15	5	70.31	103.44
69	26	5	67.65	113.89
64.5	30	5.5	73.8	129.74
72	21	7	76.16	132.47
72	21	7	70.14	149.64
72	21	7	77.56	139.06
72	21	7	75.44	141.60
82.5	10	7.5	82.16	163.63
82.5	10	7.5	82.01	152.43
64.4	26.2	9.4	90.8	179.39
60.5	30	9.5	93.7	179.78
78	12	10	98.54	181.06
75	15	10	93.84	189.24
68	22	10	90.84	194.56
100	-	-	49.96	113.49
-	100	-	31.40	181.30
-	-	100	470.32	373.16

Tannins are known to present in food legumes and moringa that decrease the protein quality of foods and interfere with dietary iron absorption (De Lumen and Salamat, 1980). According to Adeparusi (2001), tannins affect protein digestibility and adversely influence the bioavailability of non-haem iron (obtained from plant sources) leading to poor iron and calcium absorption. The author also reported that carbohydrate content is affected by tannins resulting in reduced energy value of a diet containing tannin. The increment of this anti-nutritional in the gruel in line with increasing moringa proportion could have effect on nutrients bioavailability and absorption. Thus, tannin is one of the factors to be considered during optimizing the proportion of OFSP supplemented with moringa and soybean.

Although tannin has detrimental effect, it has several benefits in processed food and human health. The antimicrobial property of tannic acid can be used in food processing to increase the shelf-life of certain foods, such as catfish fillets (Chung et al., 1998). The authors added that tannins have physiological effects, such as to reduce blood pressure, decrease the serum lipid level and modulate immuno responses. It has also antimicrobial effect, which inhibits the growth of many fungi, yeasts, bacteria, and viruses in food (Chung et al., 1998; Vattem et al., 2005)

Regression model for tannin:

$Y = 86X_1 + 411X_2 + 4479X_3 -545X_1X_2-4551\, X_1X_3-5158\, X_2X_3$ ……………..Equation (18)

Where, X_1 = OFSP; X_2 = Soybean; X_3 = Moringa; R^2= 97.22

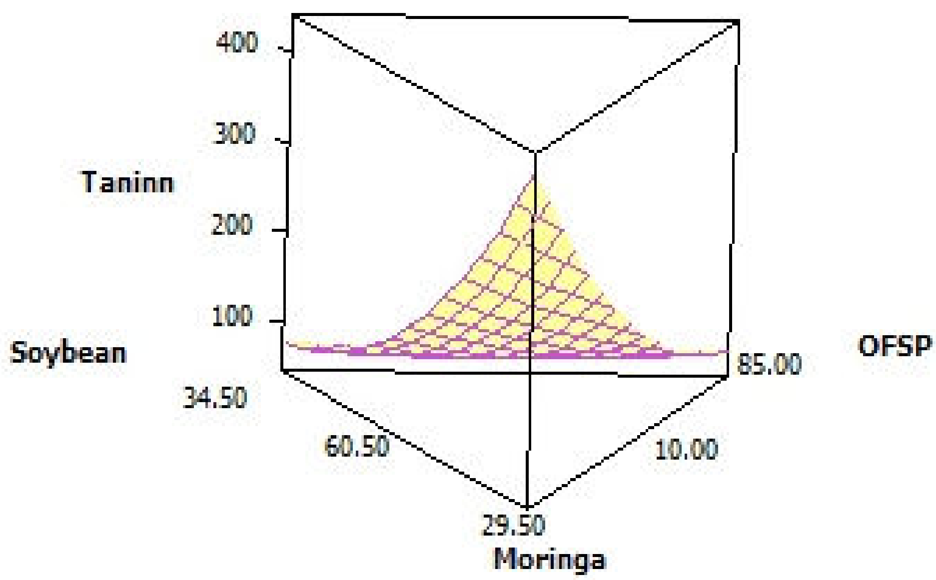


Figure 11. Response surface plot of tannin content (mg/100g) of the formulations.

Phytate content of the formulations range from 102.47 – 194.56 mg/100g and was not significantly influenced by the proportion of OFSP, soybean and moringa in both models. As the R^2 values showed the models were satisfactory and good fitting (lack-of-fit, $P > 0.05$) to both experimental results (Appendix A). Previous report showed that, phytate content is high in legumes and decreases the bioavailability of essential minerals and the bioavailability of proteins by forming insoluble phytate-mineral and phytate-protein complexes (Tajoddin et al., 2011).

4.5 Functional properties

The functional properties determine the application and use of food materials for various food products. The mean values of functional properties for porridge (gruel) such as water absorption capacity (WAC), bulk density (BD), viscosity (V) and water activity (a_w) are summarized in Table 12. The measured values were ranging from 1.65 – 2.1 ml, 0.79 – 0.83 g/ml, 77.96 –121.20 mPa.s and 0.40 – 0.4 for WAC, BD, viscosity and a_w, respectively. Analysis of variance results are also summarized in Appendix A. Models for WAC were significant ($p<0.05$), implying WAC was affected by the individual ingredient variables, OFSP, soybean and moringa in both linear and quadratic models. The models for BD, viscosity and a_w were not significant. R^2 values showed that the models were satisfactory and good fitting (lack-of-fit, $P>0.05$) to experimental results (Appendix A).

Table 12. Functional properties of the formulations.

Mixture compositions (%)			Functional properties			
OFSP	**Soybean**	**Moringa**	**WAC**	**BD**	**V**	**aw**
76	19	5	1.80	0.81	106.58	0.4
80	15	5	1.90	0.80	107.24	0.41
80	15	5	1.90	0.80	107.20	0.4
69	26	5	1.80	0.82	79.79	0.415
64.5	30	5.5	1.75	0.83	77.96	0.416
72	21	7	1.75	0.82	79.41	0.42
72	21	7	1.75	0.82	90.91	0.42
72	21	7	1.65	0.81	80.90	0.42
72	21	7	1.70	0.81	80.97	0.42
82.5	10	7.5	1.95	0.79	119.30	0.43
82.5	10	7.5	2.10	0.79	121.20	0.43
64.4	26.2	9.4	1.75	0.82	80.80	0.44
60.5	30	9.5	1.65	0.83	66.91	0.44
78	12	10	1.85	0.80	101.21	0.45
75	15	10	1.85	0.80	88.60	0.45
68	22	10	1.75	0.80	88.27	0.45
100	-	-	1.85	0.63	NA	0.45
-	100	-	1.55	0.80	NA	0.25
-	-	100	4.35	0.76	NA	0.45

WAC= water absorption capacity (ml); BD= bulk density (g/ml); V= viscosity (mPa.S); aw= water activity; NA = not analyzed.

A good quality complementary diet should have appropriate nutrient density, bulk density, viscosity, texture and consistency that allow easy consumption (WHO, 2003). WAC of the porridge (gruel) has increased as the proportion of OFSP increased in the mixture, suggesting WAC content may be associated with carbohydrate contents of OFSP. Previously, Doraska and Rollin (2003) reported that low carbohydrate content decreased the water absorption capacity of most food systems. This finding is in agreement with Iwe and Ngoddy (1998) who reported increments of WAC as sweet potato content increased in extrusion cooked soybean and sweet potato blends (Figure 12).

Regression model for water absorption capacity:

$Y = 294X_1 + 833X_2 + 46.34X_3 -11.75X_1X_2-53.43\ X_1X_3-62.09\ X_2X_3$ ....Equation (19)

Where, X_1 = OFSP; X_2 = Soybean; X_3 = Moringa; R^2= 81.73

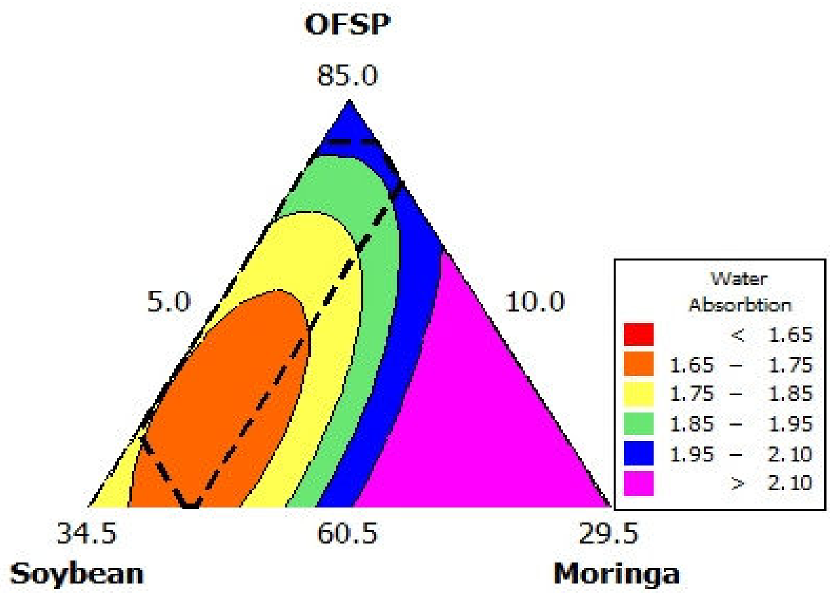


Figure 12. Contour plot of water absorption capacity content (mg/100g) of the formulations.

Other functional properties include BD, viscosity and a_w were not significantly affected by proportion of ingredients in the products (gruel). BD is a reflection of the load of the flour samples can carry if allowed to rest directly on one another. The product density influences the amount and strength of packaging material, texture or mouth feel (Karuna et al., 1996). On the other hand, viscosity, is the measure of the resistance to flow, has significant impact on food acceptability to both mothers and young children. Water activity (a_w) defines the amount of unbound water in a sample product. It is crucial to be lower in the gruel since it facilitates microbial reproduction, travel, and contamination. An appropriate a_w content (preferably lower amount) in the product is crucial for optimizing quality and safety of foods (Connick et al., 1996).

4.6 Sensory properties

Assessing acceptability of the gruel prepared from OFSP, soybean and moringa floor formulations by the target group was one of aims of the study. The mean sensory scores are summarized in Table 13. The results indicated that acceptability of color, odor, taste, consistency and overall acceptability of the products range from 2.00 – 3.58, 2.15 – 3.40, 2.40 – 3.56, 2.84 – 3.52 and 2.40 – 3.50 respectively. Appendix B summarized the ANOVA for sensory scores. The color and overall acceptability of gruel were significantly (P<0.01) affected by mixture of soybean and/or moringa with OFSP in both linear and quadratic models. However, the acceptability of odor was influenced significantly (P<0.05) in quadratic and also the taste attribute of the products was significantly (p<0.05) affected in linear model, but not in quadratic one. In contrast to taste, consistency of gruels was significantly (p<0.05) influenced by mixtures in quadratic rather than linear model. As R^2 values apparent in Appendix B, both models were satisfactory and good fitting (lack-of-fit, P > 0.05) to experimental results.

Table 13. Mean scores of sensory for samples evaluated by untrained panels.

Mixture compositions (%)			Sensory Attributes				
OFSP	**Soybean**	**Moringa**	**Color**	**Odor**	**Taste**	**Con.**	**OA**
76	19	5	3.10	3.20	3.52	3.32	3.36
80	15	5	3.58	3.14	3.42	3.44	3.40
80	15	5	3.50	3.16	3.38	3.36	3.46
69	26	5	3.06	3.30	3.46	3.26	3.48
64.5	30	5.5	3.14	3.40	3.56	3.10	3.50
72	21	7	2.32	3.20	2.96	3.20	3.34
72	21	7	2.47	3.00	3.13	3.20	3.30
72	21	7	2.44	3.20	2.93	3.10	3.32
72	21	7	2.35	2.99	2.95	3.10	3.20
82.5	10	7.5	2.50	2.90	2.96	3.52	3.12
82.5	10	7.5	2.30	3.00	2.94	3.44	3.08
64.4	26.2	9.4	2.44	2.82	2.82	3.00	2.94
60.5	30	9.5	2.38	2.72	3.08	3.06	2.82
78	12	10	2.28	2.50	2.80	3.26	2.46
75	15	10	2.00	2.24	2.44	2.90	2.42
68	22	10	2.20	2.15	2.40	2.84	2.40

Con= consistency; OA= overall acceptance; values indicating that 5- like very much, 4- like, 3- neither like or dislike, 2- dislike and 1- dislike very much.

Colour, which is a sensation that forms part of the sense of vision, judges the appearance of a food (Jellinek, 1985). The mean score data for the various optimized formulations shows that, product number two has scored highest for color. This formulation as shown in Table 13 had the minimum content of moringa (5%), medium soybean (15%) and maximum OFSP content (80%). the result was in agreement with the work of (Quarcoo, 2008). According to the report of Sengev et al., (2012), as the level of supplementation of moringa powder on wheat flour increased to prepare bread, the degree of likeness for crust and crumb was decreased because of the green colour of the bread imparted by the chlorophyll content of the leaves. The sensory data for color was fitted to a regression model by using transformation of log and it was reasonably accurate, showing R^2 of 93.61 (Eq 20). Contour plots were generated using the predictive model to graphically display the influences of the components on color (Figure 13). The figure showed that decreasing the proportion of moringa powder in the formulation to its minimum improved the color appreciation by the panelists. This could be attributed to consumers not being familiar with green products, and hence the less green the color of the porridge the higher it was scored.

Regression model for color

$Y = 3.6X_1 + 6.2 X_2 + 198.1 X_3 - 8.1X_1X_2 - 245.4X_1X_3 - 223.1X_2X_3$ …………..Equation (20)

Where, X_1 = OFSP; X_2 = Soybean; X_3 = Moringa; R^2= 93.61

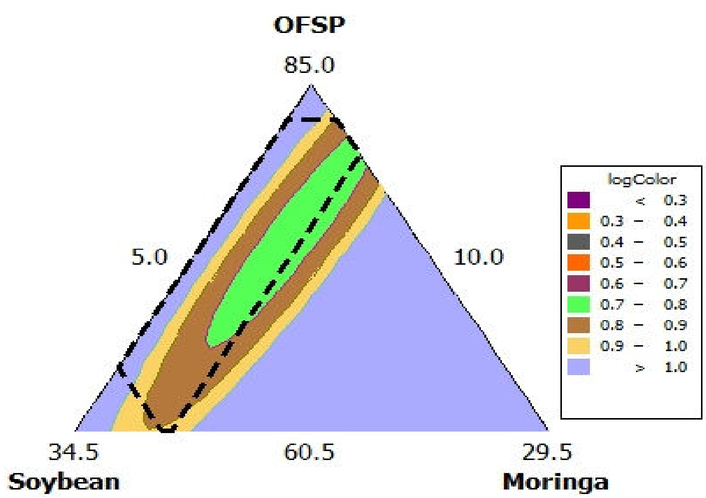


Figure 13. Contour plot for color acceptance of formulated products.

Porridge made from 64.5 % OFSP, 30 % soybean and 5.5 % moringa (product 5) gave an odour that was most accepted with a mean score of 3.40 (Table 13, Figure 14). The least acceptable odor (mean score = 2.15) was recorded for product number 16 that had the highest amount (10%) of moringa, the lowest proportion of OFSP (68 %) and moderate quantity of soybean (22 %). This result was in agreement with the reports of Sengev et al. (2012), Quarcoo (2008). The regression model did not suffer from lack of fit.

Regression model for odor;

$Y = 2.2X_1 + 11.5X_2 - 340.8X_3 - 12.2X_1X_2 + 386X_1X_3 + 363.5X_2X_3$ …………………Equation (21)

Where, X_1 = OFSP; X_2 = Soybean; X_3 = Moringa; R^2 = 91.94

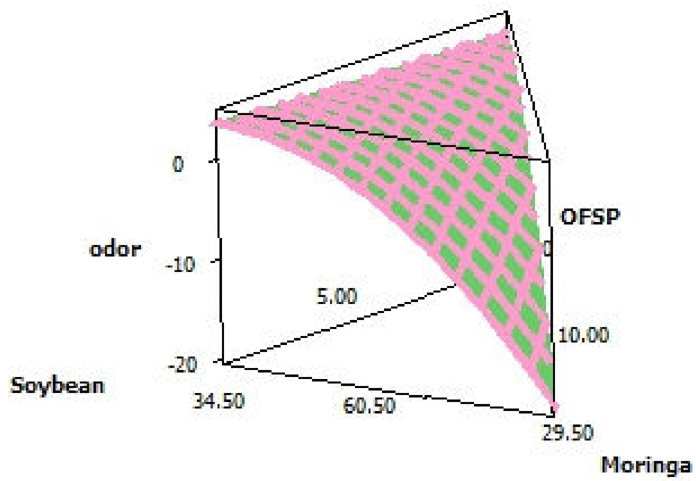


Figure 14. Response surface plot of odor of gruel samples.

On the other hand, the contour plots for taste and the model could explain 95% of the variations due to taste (Figure 15). The highest mean score, for taste was obtained when highest proportion of soybean (30%) was used. The taste of the porridge was scored the highest with minimum moringa levels and was slightly disliked with maximum level. The result was in agreement with previous works (Dachana et al., 2010 and Quarcoo, 2008).

Regression model for taste;

$Y = 13.5X_1 + 53.5X_2 + 387.9X_3 - 65.6X_1X_2 - 499.8X_1X_3 - 532.5\ X_2X_3$ ……..Equation (22)

Where, X_1 = OFSP; X_2 = Soybean; X_3 = Moringa; R^2 = 92.28

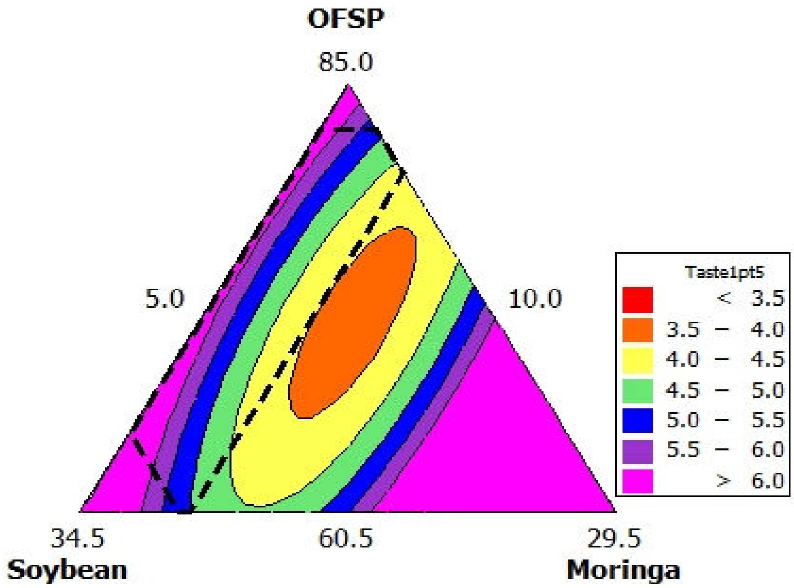


Figure 15. Contour plot for taste acceptance of gruel samples.

The least score for consistency was obtained for product 15 and 16 (Table 13) with high amounts of moringa. Dachana et al. (2010) carried out studies on the development of nutritious cookies prepared from wheat and moringa flours. They reported that addition of above 15% level of moringa flour adversely affected the mouth feel of biscuits. While the highest mean score (3.52) was obtained for product 10, which had maximum amounts of OFSP. Thus high amounts of OFSP in the product may have increased the score for consistency. This may be due to the starchiness of OFSP. Response surface plot obtained from the regression model for consistency (Figure 16) showed that OFSP at its maximum level gave porridge that was slightly liked by consumers. As the compositions of moringa increased, the consistency score of the formulations has decreased.

Regression model for consistency;

$Y = 4.74X_1 + 12.27X_2 - 61.32\, X_3 - 18.57\, X_1X_2 + 63.98X_1X_3 + 69.94X_2X_3$ …….Equation (23)

Where, X_1 = OFSP X2 = Soybean X3 = Moringa; R^2 = 87.22

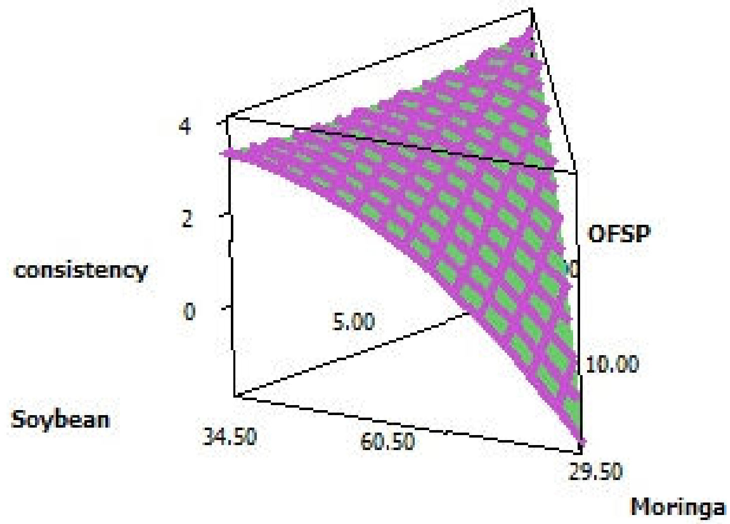


Figure 16. Response surface plot of consistency of samples.

The contour graph for overall acceptability is represented in Figure 17. Products with higher OFSP and/or soybean amount were the most accepted by the consumers. On the other hand, porridges made with the minimum level of moringa had the highest mean score for overall acceptability (Sengev et al., 2012, Dachana et al., 2010 and Quarcoo, 2008).

Regression model for overall acceptance

$Y = 2.7X_1 + 4.7X_2 - 342.4X_3 - 3.9X_1X_2 + 379.8X_1X_3 + 394.2X_2X_3$ ……………..Equation (24)

Where, X_1 = OFSP; X_2 = Soybean; X_3 = Moringa; $R^2 = 97.31$

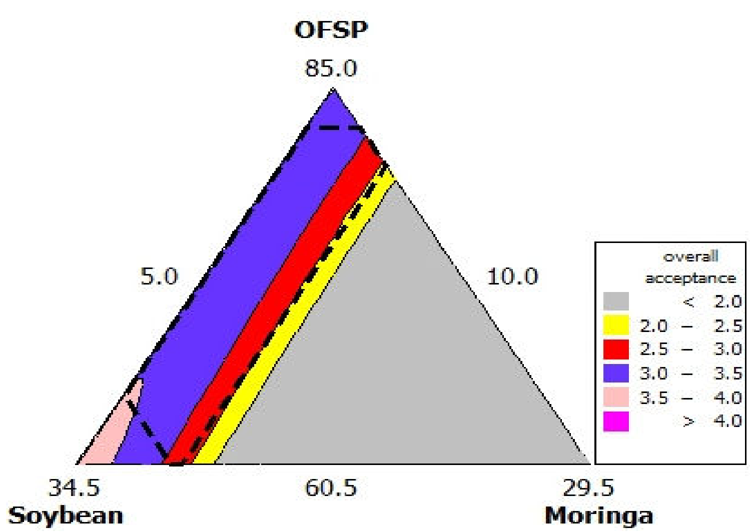
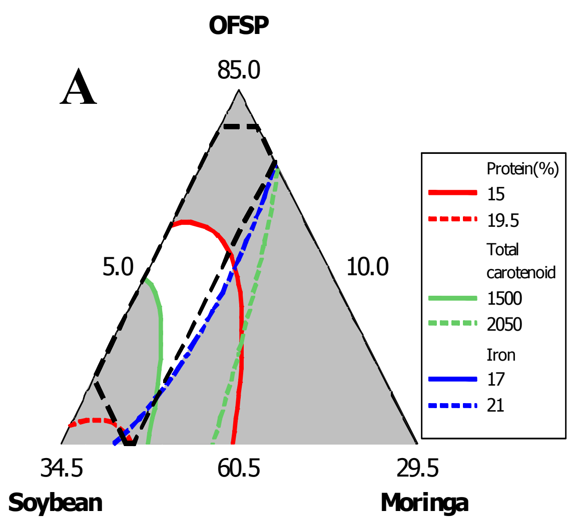
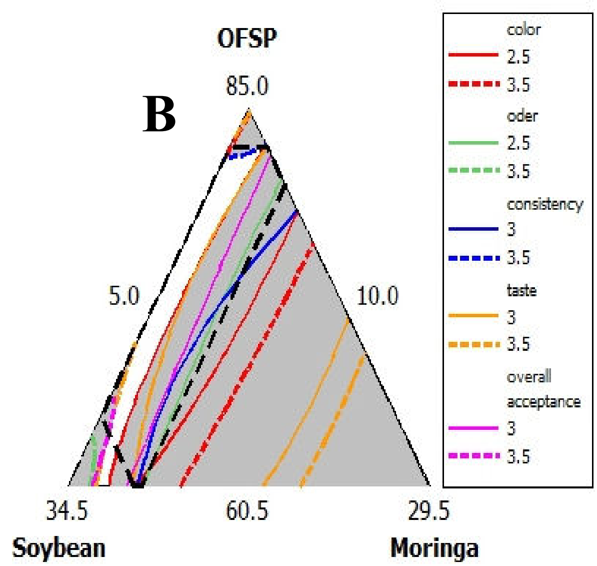


Figure 17. Contour plot of the overall acceptance of samples.

4.7 Optimal mixture compositions

The study focused on determining the optimal formulation that is suited to produce fortified product with desirable nutrient compositions. Graphical optimization was employed in order to determine the optimum formulation. Superimposition of contour plot regions of interest (protein > 15 %, total caroteinoid > 1500µg/100g, iron > 17mg/100g and each sensory attribute received hedonic ratings of > 3.0) resulted in optimum regions for OFSP enriched with soybean and moringa porridge formulation (Figure 18).





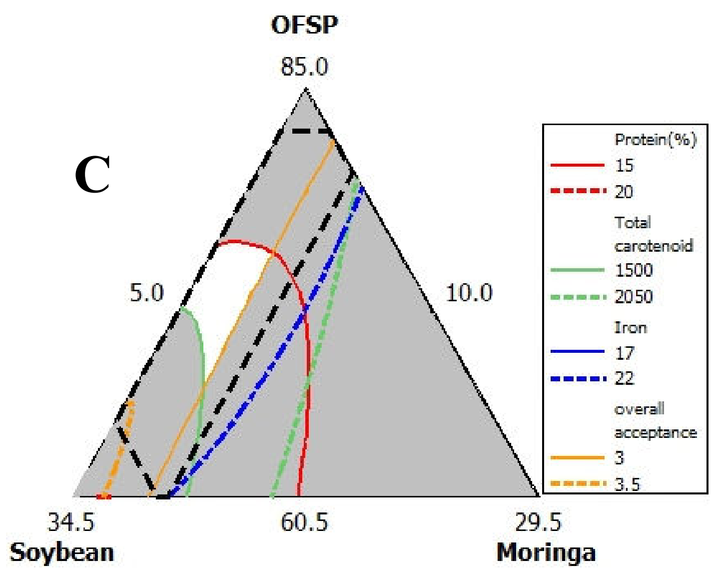


Figure 18. Superimposed contour plots showing optimal regions. **A**) the three nutrient compositions (protein, total carotenoid and iron); **B**) sensory attributes, and **C**) combination of nutrients and overall acceptability of a product.

The white region in Figure 18A indicated that any point within this region represents an optimum combination. Product with 65-75% OFSP, 18-25% soybean and 6-9%moringaresults in desirable protein, total carotenoid and iron contents. Similarly, the white region of Figure 18B shows sensorially optimal formula. Point prediction shows that 64-82% OFSP, 12-30 % soybean and 5-6.5% moringa provides desirable consumer acceptability for the sensory attributes. Since acceptability of the product by consumers is an essential parameter, superimposition of contour plot regions consisting of desirable nutrients and sensory acceptability of several formulations of these commodities was made (Figure 18C). Thus, the optimum values that have feasible nutrient content and consumer's overall acceptability were 67-75% OFSP, 17-23% soybean, and 5-8% moringa.

All in all, OFSP enriched with soybean and moringa formulated gruel consisted of optimal total carotenoids content. Carotenoids have been correlated with the enhancement of immune system and with alleviating Vitamin A deficiency. Vitamin A is present in the form of provitamin A in plants. The most important carotenoid which are precursors of vitamin A in humans beings are β-carotene, α-carotene and β-cryptoxanthin (Jaarsveld et al., 2005), but β-carotene is the major provitamin A of most carotenoid containing foods (Vimala et al., 2011). Total carotenoid content may be directly related to the color of OFSP, confirming that color intensity used as an indication of pro-vitamin A value in sweet potatoes (Hagenimana et al., 2011). Thus, consumption of OFSP through gruel may improve vitamin A status and can play a significant role in developing countries as a viable long term food-based strategy for controlling vitamin A deficiency in pregnant and breast feeding/ feeding women who have a direct link to children. Apart from nutritional values, the gruel can also introduce OFSP crop to the societies and farmers producing the crops gain economic benefits.

The results also indicated that there may be a possibility to make a product which contains optimal levels of iron sufficient enough for combating iron deficiency in pregnant and breast feeding women. Iron content was associated with increased proportion of moringa powder in the formulation. Around 50% of pregnant women suffer from anemia in developing countries (Yang and Huffman, 2011) and specifically in Ethiopia (Haidar et al., 2003). It has been reported that moringa is known as mother's best friend since it helps to increase milk production in breastfeeding women and is sometimes prescribed for anemia (Jongrungruangchok et al., 2010). Moringa leaves can carry out much to preserve the pregnant and breast-feeding women's health and pass on strength to the fetus or nursing child (Price, 2007). Hence, accessing of OFSP enriched with soybean and moringa provides iron and can play a key role in developing countries for sustainable long term food-based strategy to control iron deficiency in pregnant and breast feeding women.

5. SUMMARY AND CONCLUSIONS

This study was aimed at developing a new food product, which is enriched with vitamin A, protein and iron for pregnant and breast feeding women. Gruel was developed from mixture of different proportions of OFSP (60-85%), soybean (10-30%) and moringa (5-10%). The proportions of OFSP, soybean and moringa were selected using unique 16-runs, three-level D-Optimal constrained mixture design. The study assessed proximate composition, total carotenoid, minerals (Fe, Ca and Zn), functional properties and sensory attributes of the gruel.

The results indicated that significant differences ($p<0.05$) exists among the products (gruel) in protein, ash, crude fiber, iron, calcium, water absorbing capacity, tannin and sensory attributes (color, odor, taste, consistency and overall acceptability). However, there were no significant differences among the gruels in terms of total carotenoid, crude fat, carbohydrate, bulk density, viscosity, water activity and phytate contents.

Generally, proportion of OFSP, soybean and moringa induced significant changes in the gruel nutritional quality and sensory attributes evaluated. Formulas with higher proportion of OFSP and soybean (lower proportion of moringa) showed good sensory acceptability despite reduced nutritional contents that appeared for lower proportion of moringa. The results revealed that OFSP, soybean and moringa crops have impressive potential for making vitamin-A-protein-iron enriched porridge (gruel). The optimum formula containing 67-75% OFSP, 17-23% soybean, and 5-8% moringa was selected as the best formulation to yield optimum total carotene, protein and iron rich product with desirable sensory attributes. This formula can be used as a long term food-based strategy for controlling vitamin A, protein and iron deficiencies in pregnant and breast feeding women in developing countries. In addition, the study can create a good opportunity to bring the nutritional use of OFSP and moringa crops to the attention of societies.

6. FUTURE LINES OF WORK

Further studies might focus on determination of beta carotene content of the formulations using spectrophotometer and more accurately using high pressure liquid chromatography (HPLC). Investigating protein and starch digestibility of the product and analyzing nutrients which were not covered by this study such as amino acids and fatty acids profiling, anti-nutrients (trypsin inhibitors), mineral elements and water solubility index is also recommended. The other important point that would be needed to verify will be the nutritional contents using various processing methods, which play a significant role on reduction of anti-nutritional factors on moringa leaves and prevention of beta carotene degradation on OFSP.

Additionally, it might be crucial if the product's acceptability is improved through descriptive sensory evaluation using different ingredients and large sample size, especially regarding the color of the product; and to study the possibilities of processing the acceptable product at house, cottage and large scale food processing. So far, there is a limited awareness about the nutritional benefit of OFSP and moringa crops in most parts of Ethiopia, which have suitable climatic condition to grow these plants. As a result, strong attention should be given to execute further work on promotion of the crops and their value added products in wider location and societies of Ethiopia.

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8. APPENDICES

Appendix A. Analysis of variance (ANOVA) for mixture compositions showed the p-value of proximate analysis.

Sources	Linear	Quadratic	A*B	A*C	B*C	LoF	R^2
Moisture	0.904	0.385	0.260	0.632	0.835	0.815	74.46
Protein	0.000	0.010	0.055	0.003	0.002	0.194	99.79
Fat	0.543	0.788	0.601	0.564	0.669	0.452	88.96
Ash	0.003	0.004	0.001	0.024	0.030	0.663	93.69
Fiber	0.002	0.008	0.003	0.070	0.153	0.795	92.22
Carb.	0.051	0.092	0.051	0.883	0.840	0.610	96.76
Total carotenoid	0.707	0.829	0.714	0.521	0.444	0.199	90.99
Fe	0.002	0.004	0.001	0.042	0.038	0.175	92.60
Ca	0.004	0.009	0.009	0.007	0.006	0.107	96.32
Tannin	0.005	0.011	0.003	0.047	0.030	0.792	97.22
Phytate	0.164	0.238	0.178	0.264	0.426	0.422	96.83
WAC	0.071	0.029	0.170	0.738	0.614	0.475	81.73
BD	0.475	0.889	0.692	0.581	0.559	0.241	87.62
V	0.651	0.187	0.067	0.389	0.491	0.084	89.38
aw	0.057	0.061	0.124	0.431	0.168	0.262	96.57

A= OFSP, B= Soybean, C= Moringa, LoF = Lack-of-Fit, WA= water absorption capacity (%); BD= bulk density (g/ml); V= viscosity (mPa.S); aw= water activity, R^2 = determination coefficient

Appendix B. ANOVA for mixture compositions showing p-values of sensory attributes.

Sources	Color*	Odor	Taste**	Con.	OA
Linear	0.003	0.009	0.022	0.103	0.001
Quadratic	0.002	0.028	0.037	0.033	0.002
A*B	0.044	0.173	0.009	0.008	0.452
A*C	0.001	0.008	0.113	0.436	0.000
B*C	0.001	0.012	0.098	0.403	0.000
Lack-of-Fit	0.095	0.176	0.067	0.099	0.114
R^2	93.61	91.94	92.28	87.22	97.31

A= OFSP; B= Soybean; C= Moringa; Con.= consistency; OA= over all acceptance; *transformed by log; **transformed by 1.5, R^2 = determination coefficient

Appendix C. Estimated regression coefficients of proximate compositions of individual and mixed products.

	Moisture		**Protein**		**Fat**		**Ash**		**Fiber**		**Carbohydrate**	
	RC	**SE**	**RC**	**SE**	**RC**	**SE**	**RC**	**SE**	**RC**	**SE**	**RC**	**SE**
A	12.7	5.11	4.3	0.90	6.5	5.48	5.22	0.26	1.9	1.02	69.5	5.49
B	15.3	30.88	27.7	5.45	39.3	33.11	10.98	1.55	27.7	6.18	-20.9	33.15
C	262.8	563.47	-368.4	99.51	319.9	604.13	82.34	28.34	-205	112.84	8.4	605.02
A*B	-56	46.88	18	8.28	-27.1	50.27	-10.7	2.36	-35	9.39	111.8	50.35
A*C	-326.7	660.65	462.6	116.67	-423	708.32	-88.26	33.23	268.7	132.31	106.7	709.37
B*C	-143.2	670.73	486.4	118.45	-317	719.12	-85.25	33.74	207.9	134.32	-148.9	720.18

A= Orange fleshed sweet potato, B= Soybean and C= Moringa. RC= Regression coefficient; SE= standard error,

Appendix D. Estimated regression coefficients of total carotenoid and minerals of individual and mixed products.

	Total carotenoid		**Iron (Fe)**		**Calcium (Ca)**	
	RC	**SE**	**RC**	**SE**	**RC**	**SE**
A	2405	472	26	3.47	64	18.10
B	1874	2852.7	114	21.07	366	109.39
C	62399	52058.5	956	384.49	7290	1996.18
A*B	-3074	4331.9	-153	31.99	-540	166.11
A*C	-66419	61036.7	-1050	450.79	-7960	2340.45
B*C	-76629	61967.4	-1096	457.67	-8250	2376.14

A= Orange fleshed sweet potato, B= Soybean and C= Moringa. RC= Regression coefficient; SE= standard error.

Appendix E. Estimated regression coefficients of functional properties of individual ingredient and their mixed products.

	WAC		BA		V		WA	
	RC	SE	RC	SE	RC	SE	RC	SE
A	2,94	0.435	0.770	0.041	241	45.77	0.366	0.028
B	8.33	2.631	1.028	0.249	393	276.65	0.761	0.162
C	46.34	48.001	-1.947	4.556	4158	5048.50	3.993	2.953
A*B	-11.75	3.995	-0.155	0.379	-863	420.02	-0.413	0.246
A*C	-53.43	56.287	3.044	5.341	-5330	5919.18	-2.844	3.463
B*C	-62.09	57.144	3.281	5.423	-4300	6009.44	-5.225	3.516
R^2	81.73		87.62		89.38		96.57	

A= Orange fleshed sweet potato, B= Soybean and C= Moringa. RC= Regression coefficient; SE= standard error.

Appendix F. Estimated regression coefficients of anti-nutritional factors (tannin and phytate mg/100g)) contents in individual and mixed products.

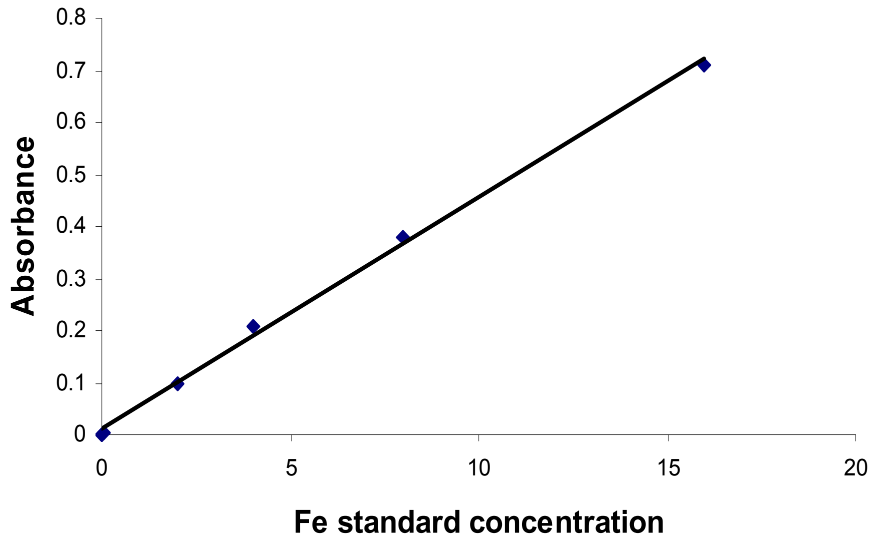
	Tannin		phytate	
	RC	SE	RC	SE
A	86	15.56	-21	48.96
B	411	94.04	517	295.93
C	4479	1716.1	-4511	5400.41
A*B	-545	142.8	-652	449.38
A*C	-4551	2012.0	7500	6331.78
B*C	-5158	2042.7	5336	6428.33

A= Orange fleshed sweet potato, B= Soybean and C= Moringa. RC= Regression coefficient; SE= standard error.

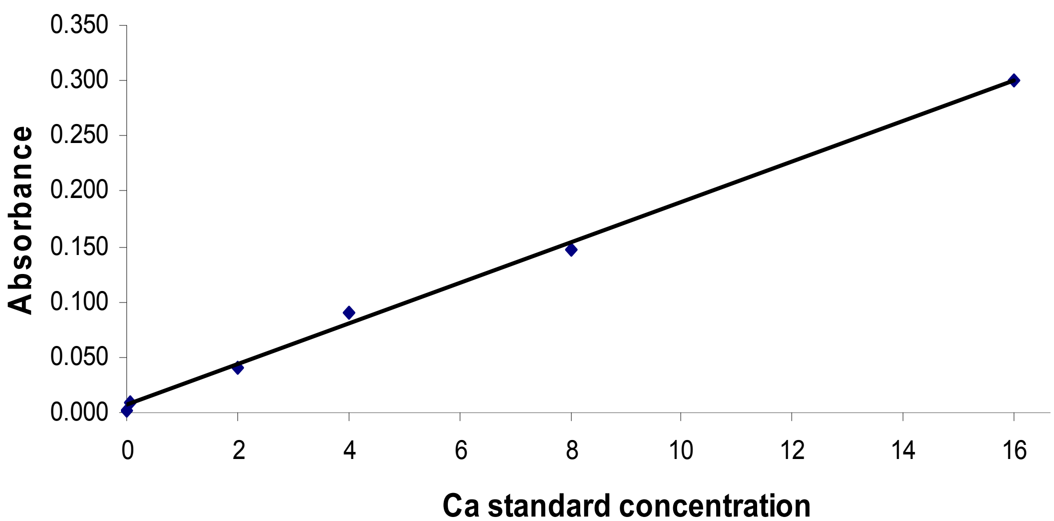
Appendix G. Estimated regression coefficients of sensory attributes of individual ingredient and their mixed products.

	Color		Odor		Taste		Consistency		OA	
	RC	SE	RC	SE	RC	SE	RC	SE	RC	SE
A	10.2	1.05	2.2	0.907	6.1	0.896	4.74	0.609	2.7	0.549
B	16.2	6.341	11.5	5.484	21.4	5.415	12.27	3.685	4.7	3.321
C	602	115.72	-340.8	100.07	126.2	98.825	-61.32	67.244	-342.4	60.598
A*B	-20.9	9.629	-12.2	8.327	-25.6	8.223	-18.57	5.595	-3.9	5.043
A*C	-742.4	135.68	386	117.33	-164.7	115.87	63.98	78.841	379.8	71.049
B*C	-675.9	137.75	363.5	119.15	-175.3	117.64	69.94	80.043	394.2	72.132

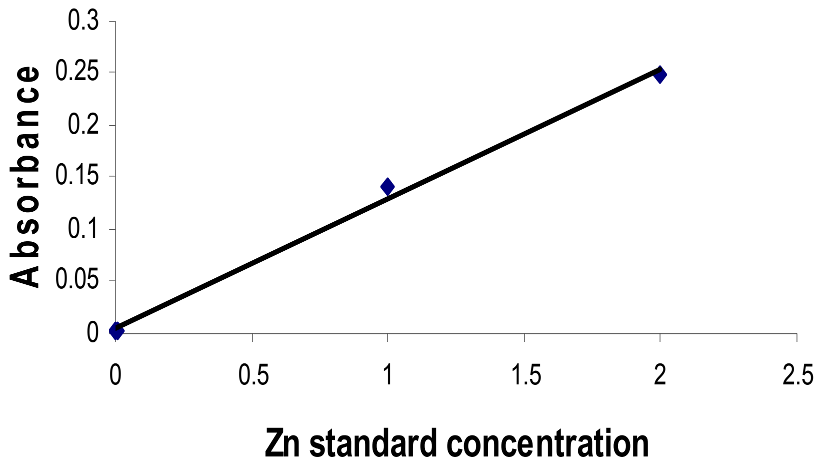
A= OFSP; B= Soybean; C= Moringa; O. Acceptance= over all acceptance; RC= Regression coefficient; SE= standard error.



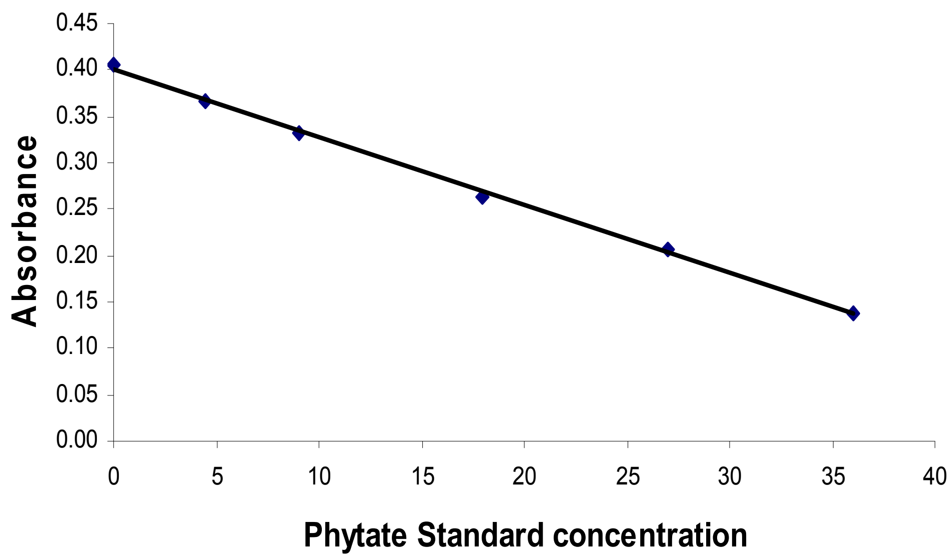
Appendix H. Calibration curve of Iron.



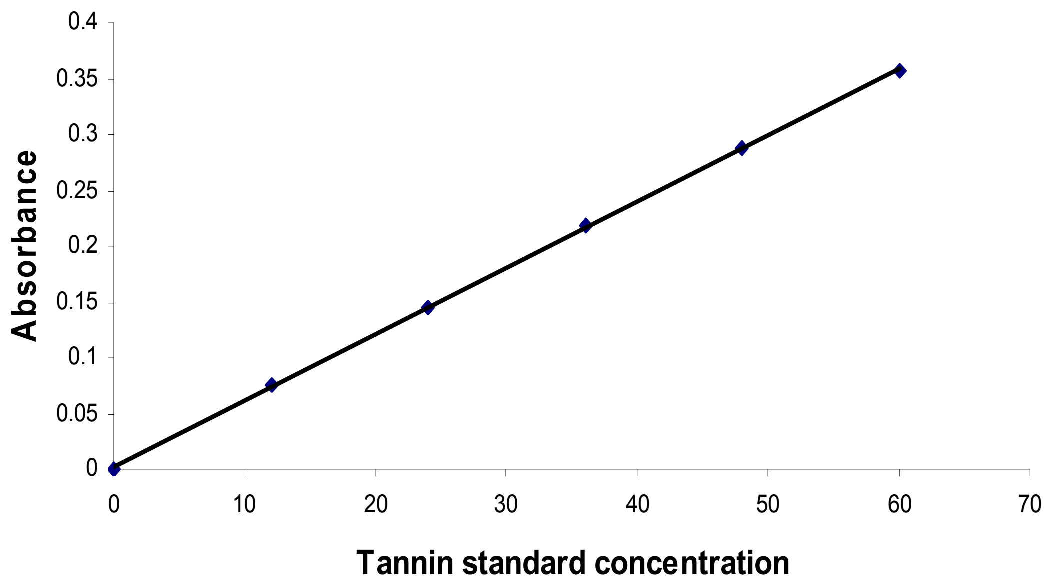
Appendix I. Calibration curve of calcium.



Appendix J. Calibration curve of zinc



Appendix K. Calibration curve of phytate



Appendix L. Calibration curve of tannin

Appendix M. Sensory evaluation questionnaire form

Ballot for porridge hedonic test using a five point scale

Please look at and taste each sample of porridge in order from left to right. Indicate how much you like or dislike each sample by checking the appropriate phrase of category which is listed below and mark your choice with the number that corresponds to your preference on each parameter.

1. Dislike Very Much
2. Dislike
3. Neither Like or Dislike
4. Like
5. Like Very Much

Sample code	color	Odor	Taste	Consistency	Overall acceptability