NUTRITIONAL AND SENSORY QUALITY OF COMPLEMENTARY FOOD BLENDED FROM QUALITY PROTEIN MAIZE, *ANCHOTE* (*Coccinia abyssinica*), CARROT AND SOYBEAN

MSc. THESIS

By

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JUNE, 2016
JIMMA, ETHIOPIA

NUTRITIONAL AND SENSORY QUALITY OF COMPLEMENTARY FOOD BLENDED FROM QUALITY PROTEIN MAIZE, *ANCHOTE* (*Coccinia abyssinica*), CARROT AND SOYBEAN

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Submitted to School of Graduate Studies Jimma University College of Agriculture and Veterinary Medicine

In Partial Fulfillment of the Requirements for the Degree of Master of Science in Postharvest Management (Durable Crops)

By

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Name of Student: Tsigereda Kebede ID No. MSc. 06064/06

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I have completed my Thesis research work as per the approved internal defense and it has been evaluated and accepted by my advisors. Hence, I hereby kindly request the department to allow me to present the findings of my work and submit the Thesis.

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We, the Thesis advisors have evaluated the contents of this Thesis and found to be satisfactory, executed according to the approved proposal, written according to the standards and format of the university, and are ready to be submitted. Hence, we recommend the Thesis to be submitted.

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Decision/suggestion of department graduate council (DGC)

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Chairperson of DGC Name Signature Date

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DEDICATION

This Thesis is dedicated to my beloved parents, my mother, Felekech Segude and my father, Kebede Zegeye for nursing me with affection and love and for their parental devotion in the success of my endeavors.

STATEMENT OF AUTHOR

I, the undersigned, declare that this Thesis is my original work and all sources or materials used for this Thesis have been properly acknowledged. This Thesis is submitted in partial fulfillment of the requirements for MSc. degree in Postharvest Management at Jimma University. I dully declare that this Thesis is not submitted to any other institutions anywhere for the award of any academic degree, diploma or certificate.

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BIOGRAPHICAL SKETCH

The author, Tsigereda Kebede Zegeye, was born on September 18, 1985 at Bale Goba South east Ethiopia. She attended Elementary school in Urjji Berisa, Secondary and preparatory school in Batu Terara high school. She has successfully passed the Ethiopian School Leaving Certificate Examination (ESLCE) in 2004, and joined Mekelle University College of Agriculture in 2005. After three years of study, she graduated with B.Sc. degree in Dry Land Crop and Horticultural science under Agronomy stream in August, 2008. After graduation, she had worked for four years in different organizations from December 2009 to August 2013. In September 2013, she joined the School of Graduate Studies of Jimma University College in Agriculture and Veterinary Medicine to pursue Master of Science Degree in Postharvest Management.

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LIST OF ABBREVIATIONS & ACRONYMS

AOAC	Association of Official Analytical Chemists
ATA	Agricultural transformation agency
ASA	American Soybean Association
CAC	Codex Alimentarius Commission
CASCAPE	Capacity Building for Skilling up of Evidence- based best Practices in Agricultural Production in Ethiopia
CIDA	Canadian International Developmental Agency
CIMMIT	International Maize and Wheat Improvement Center
CSA	Central Statistical Agency
DFATD	Department of Foreign Affairs, Trade and Development
DOE	Design of Experiment
EATA	Environmental Agriculture and Technology Academy
ECX	Ethiopian commodity exchange
EDHS	Ethiopian Demographic and Health Survey
EPHI	Ethiopian Public and Health Institute
ENI	Ethiopian Nutrition Institute
JARC	Jimma Agricultural Research Center
JHBSPH	John Hopkins Bloomberg School of Public Health
JUCAVM	Jimma University College of Agriculture and Veterinary Medicine
Kcal	Kilo calorie
MAFA	Monitoring African Food and Agriculture
MOARD	Ministry of Agriculture and Rural Development
NAS	National Academy of Sciences
NYCW	Nutrition Young Children and Women
OAC	Oil Absorption Capacity
PAHO	Pan American Health Organization
PEM	Protein Energy Malnutrition
QPM	Quality Protein Maize
SAM	Severe Acute Malnutrition
SCN	Sustainable Communities Network
SNNPR	Southern Nations Nationalities People’s Region
SSA	Sub Saharan Africa
UNICEF	United Nations Children Emergency Fund
USAID	United States Agency for International Development
WAC	Water Absorption Capacity
OAC	Oil Absorption Capacity
CRDRIV	Committee to Review Dietary Reference Intakes for Vitamin

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ABSTRACT

Cereals-based complementary foods are commonly used in resource poor settings in developing countries. However, they are characterized by poor nutritional quality both in terms of macro and micro nutrients. This study, aimed to develop nutritionally enriched and sensorial accepted QPM based complementary food from locally available food sources. Seventeen formulations of the composite flours were prepared using D-optimal mixture design with the aid of, Design-Expert software version 8.0 with a range for QPM 45-85%, Anchote 10-20%, Carrot 5-15% and Soybean 0-20%. Standard methods were used to conduct chemical analysis and sensory evaluation of the complementary foods. The major response variables of nutritional composition, anti-nutritional factors, and functional (Physical) proprieties and sensory acceptability of formulations after cooking were investigated. Results showed that a significant difference ($P<0.05$) in protein, fat, carbohydrate, energy, beta carotene, Calcium and tannin content of porridge prepared from different blending ratio of ingredients. Protein, carbohydrate , calorie , β-carotene, Calcium, Iron and Zinc content of the porridge ranged from 10.25-19.01%, 58.05-70.32%, 368.38-398.7 kcal/100g, 1165-2215μg/100g, 101.69-204.80 mg/100g, 5-6.99mg/100g and 2.205- 3.250 mg/100g. Increasing trend was observed in the protein content of the complementary food with an increase in the proportion of soybean. There is an increasing trend in the β-carotene content of the porridge with an increasing proportion of carrot. Results also indicate that an increase in the proportion of Anchote flour in the composite flour resulted in parallel increase in the Calcium content of porridge. Increasing trend was observed in the carbohydrate content of the complementary food with an increase in the proportion of QPM and Anchote flour. Results also indicated that an increase in the proportion of QPM flour and Anchote flour resulted in parallel increase in the phytate and tannin contents. Sensory evaluation results showed that the mean score of overall acceptability ranged between, 3-4.78. The optimized proportions for that above results were QPM (55%), Anchote (10%), Carrot (15%) and Soybean (20%) blending ratios. Overall, it can be concluded that locally available and low cost food ingredients used in the present study have good potential to develop complementary foods with enhanced nutritional value and sensorial acceptability for resource-poor households.

Key words: Complementary food, Nutrition, D-optimal Mixture Design, Composite flour, Porridge, Optimization.

1. INTRODUCTION

1.1.Background

Breast milk is the perfect food for the infant during the first 6 months of life UNICEF (2006) because it contains all the nutrients and immunological factors an infant requires in maintaining optimal health and growth (Onabanjo *et al*., 2009). However, at about 6 months, the supply of energy and some nutrients from breast milk is no longer adequate to meet an infant's needs, hence; complementary feeding becomes necessary to fill the energy and nutrient gap (Dewey and Brown, 2003). Complementary feeding is the process starting when breast milk is no longer sufficient to meet the nutritional requirements of infants, and therefore other foods and liquids are needed, along with breast milk **(**WHO, 2009**).** The target range for complementary feeding is generally taken to be 6 to 23 months of age (WHO, 2008**),** even though breastfeeding may continue beyond two years **(**PAHO/WHO, 2002**).**

Infants and young children are particularly vulnerable to malnutrition during the transition period when complementary feeding begins, at six months (WHO-UNICEF, 2003). Complementary feeding is an effective child survival strategy and is ranked among the top life-saving interventions for children under 5 years and can prevent about 6% of under-five mortality (Jones *et al*., 2003). Henry and others (2015) reported that improving the quality of complementary food is one of the most cost effective strategies for improving health, reducing morbidity and mortality of young children. Nearly one third of child deaths could be prevented by optimal complementary feeding practices (Agostoni *et al*., 2008; Gupta *et al*., 2010). Complementary foods need to be nutritionally adequate, safe, and appropriately fed in order to meet the young child's energy and nutrient needs.

Furthermore, Obse and others (2013) reported that, high β-carotene content (2176 to 2432 μg/100g) in complementary food can be developed from maize, barley, pea and carrot mix. Since, Carrot is a source of important nutritional compounds (including pro-vitamin A) through their carotenoid content, and adds flavor and texture to many diets across the world (Gocmen *et al*., 2015). QPM is considered a bio fortified food, because its nutritional profile has been improved using conventional breeding techniques. This special type of maize possesses almost double the levels of lysine and tryptophan which are essential (amino acids) for human (Gupta *et al.,* 2010). *Anchote* is an endemic crop to Ethiopia Addis (2005) mainly to the Western part Demel (2010) is considered as one of the main source of calcium to heal broken body parts (Fikadu, 2013; Habtamu *et al*., 2014). Soybean is a good source of both protein and fat (Kim, 2009).

1.2.Statement of the Problem

Infants and young children are vulnerable to malnutrition because of their high nutritional requirements for growth and development (Blossner *et al*., 2005). Widespread malnutrition leads to high incidence of diseases and deaths among children under five years of age (Black *et al*., 2013 and Michaelsen *et al.,* 2009). Malnutrition still remains a persistent problem for young children in sub-Saharan Africa (Eshun *et al*., 2011). Ethiopia shares the same problem with many of the developing countries with high prevalence rate of malnutrition especially in rural households. Despite global efforts for improving child health through improving their nutritional status, malnutrition among children remains a significant problem in Ethiopia (Henry *et al*., 2015). In Ethiopia, children under 5 years of age suffer from unacceptably high prevalence of 44% underweight, 28% stunting, and 10% wasting respectively (CSA, 2012).

Cereal-based complementary foods are generally low in protein and are limiting in some essential amino acids, particularly lysine and tryptophan (Eshun *et al.,* 2011). The adequacy of complementary diet to meet nutrient requirements depends on the nutrient content of foodstuff used in the formulation. Different food ingredients can be used as a major source of a particular nutrient in development of cereal-based complementary foods. This necessitates the use of quality protein maize in formulation of complementary food together with foods of other nutrient sources. Moreover, supplementation of cereals with locally available legumes such as soybean, high in protein and lysine, although often limiting in sulphur-containing amino-acids, increases protein content of cereal-legume blends and their protein quality through mutual complementation of their individual amino-acids (Olapade *et al*., 2012).

In the context of Ethiopia, attempts have been made to alleviate nutritional problem by developing nutritious foods of high protein and energy value based on cereal-legume combinations using locally available food ingredients in different parts of the country. In south-western Ethiopia, Tirhas *et al*. (2015) developed orange fleshed sweet potato porridge complementary food enriched with soybean and moringa leaves. Similar efforts are undertaken to develop complementary food using sorghum based complementary food enriched with chickpea and orange-fleshed sweet potatoes (Eleni, 2014).

Even though complementary foods have a key role in alleviating nutritional deficiency problems, they are often burdened with problems, with foods being too dilute, not fed often enough or in too small amounts, or replacing breast milk while being of an inferior quality (WHO, 2009). Production of nutritious and low-cost complementary foods from locally available food can be considered as sustainable and effective solution against the prevalence of malnutrition. However, in many African countries, including Ethiopia, traditional infant foods are made from cereals, starchy roots and tubers that provide mainly carbohydrates with low quality protein (Olapade *et al*., 2012). Such a diet is bulky, has a low density of energy and nutrients and a low bioavailability of minerals, and will result in impaired growth, development, and host defense to infections (Michaelsen *et al.*, 2009). These foods are usually given too earlier or too late, which will make it insufficient to meet the nutritional needs of children (Onyango, 2003; Muhimbula, 2011).

Quality protein maize, soybean, carrot and *Anchote* are readily available foods in the Oromia region of Ethiopia. They have good nutritional attributes. Some of these crops were used in development of complementary foods by different authors (Obse, 2013; Eleni, 2014; Tirhas *et al.*, 2015), for their performance in complementary foods. The nutrient potentials of the food (QPM, *Anchote, carrot and* soybean, make it imperative that scientific studies be made on their composite for possible use as complementary foods. However, so far there is limited information on best combination of blending ratios of these ingredients that gives a complementary food with good nutritional quality and better sensory properties.

1.3.Research questions

1. How to prepare porridge from QPM, anchote, carrot and soybean composite flour?
2. Does advanced the nutritional and sensory quality of complementary food from mixes?
3. How a different processing method improves physical or functional properties of the flour?
4. Does reduced anti-nutritional contents by different processing methods?
5. How to optimized best nutritional quality and sensory acceptability of complementary foods?

1.4. Objectives of the study

1.4.1. General objective

The general objective of this research work was to develop nutritionally enhanced QPM based complementary food with good sensorial acceptability for children under the age of five years.

1.4.2. Specific objectives

I. To determine the optimum formulation to develop complementary food with better nutritional quality in relation to target nutrients.
II. To determine the optimum blending ratio that gives a complementary food with improved physical or functional properties with reduced anti-nutritional contents.
III. To evaluate the best sensorial acceptability of developed complementary foods
IV. To optimize best composition in terms of nutritional composition and sensorial acceptability.

1.5. Significance of the study

The significance of the study is to contribute/reduce the impacts associated with malnutrition through the formulation of blend using quality protein maize, anchote, carrot and soybean with better nutritional and sensory qualities with reduced anti-nutritional constituents. Therefore, the outcome of this research will not only be determining the best formulation of the food product, but also to provide valuable research based information for consumers, researchers, manufacturers and policy makers.

2. LITERATURE REVIEW

2.1.The Status of Child Malnutrition

Adequate nutrition and health care during the first two years of infant life is fundamental to prevent undernutrition and child death (Ouedraogo *et al.,* 2008). Child malnutrition is a major global health problem, leading to morbidity and mortality, impaired intellectual development and working capacity, and increased risk of adult disease (Gastel *et al*., 2005; Yewelsew, 2006; Kim *et al.,* 2009). Worldwide, by 2010 it was found that about 104 million children under five years of age were underweight and 171 million were stunted (Lutter *et al*., 2011). The order of magnitude of this estimate suggests that severe malnutrition in children is an important public health problem (UNICEF, 2014). In the developing world, it is estimated that child undernutrition is responsible for nearly 3.5 million deaths, 54% of under-five mortality were reported by Muller and Krawinkel (2005) 35% of the disease burden in this age group. Child under-nutrition is one of the most serious public health problems in Ethiopia. According to the Demographic and Health Survey of 2011, about 44% of children were stunted, 29% underweight and 10% were wasted, which is the highest in the world (Mekdes *et al*., 2015). Similarly, in Oromia region, Hornik, *et al.* (2015) reported that 40% stunted and 24% underweight among age of five at house hold level. Recently, Nejat (2015) from 558 under two children 13% underweight, 25% stunted and 9.7% wasted respectively.

2.1.1. Protein energy malnutrition (PEM)

Protein-energy malnutrition generally occurs during the crucial transitional phase when children are weaned from liquid to or fully adult foods (Brunken, 2006 and Silvia, 2009). During this period, children need nutritionally balanced, calorie-dense complementary foods in addition to mother’s milk because of the increasing nutritional demands of the growing body. PEM among children is the major health challenges in developing countries (FAO, 2001). It is by far the most lethal form of malnutrition and an imbalance between the supply of energy, protein, and the body’s demand for them to ensure optimal growth and function.

According to USDA, (2002) reported that the most widespread and serious health problem of children in the world being moderate or severe forms of malnutrition (USDA, 2002).

Although children of some developing nations dramatically exemplify this type of malnutrition, it can occur in persons of any age in any country (Ahima, 2011). Deficiencies of protein and energy usually occur together, but when one predominates and the deficit is severe, kwashiorkor (primarily protein deficiency) or Marasmus (predominantly energy deficiency) results (Meseret, 2011). This problem is ascribed to the unsuitable complementary feeding practices, low nutritional quality of traditional complementary foods and high cost of quality protein-based complementary foods (Black, 2013; FAO, 2004). According to Krishnan *et al*. (2012), PEM is measured in terms of underweight (low weight for age), stunting (low height for age) and wasting (low weight for height). The most important nutrition problems documented in Ethiopia are protein energy malnutrition and micronutrients deficiency (vitamin C, vitamin A, iodine, iron and zinc deficiencies). In fact it is a good basic in the preparation of baby complementary foods, which can be enriched with protein- rich foods such as soybean (Adenuga, 2010).

2.1.2. Vitamin A deficiency

Vitamin A deficiency is considered as one of the most prevalent nutritional disorders in children all over the world (FAO, 2009). The World Health Organization (2013) estimates that globally, about 190 million children under five (33.3% of the preschool age population) are vitamin A deficient, with about 5.2 million affected by night blindness (Kramer and Kakuma, 2009). In Ethiopia, vitamin A deficiency leads to 80,000 deaths a year and affects 61% of preschool children (Abrha *et al.*, 2016). Infants as well as young children have increased vitamin A requirements to support rapid growth and combat infections. In Ethiopia where the intake of vitamin A is inadequate, provision of the vitamin through a combination of breastfeeding, dietary improvement, and supplementation was recommended. Therefore, efforts were made in developing countries to incorporate beta carotene the crops like carrot which can be converted to Vitamin A in the body (Garande and Patil, 2014).

2.1.3. Calcium deficiency

Calcium is the major component of bone and assists in teeth development and it is necessary for blood coagulation and for the integrity of intracellular cement substances (Okaka and Okaka, 2001). It also promotes healthy digestion through the production of hormones and enzymes; it helps nerves pass the electrical messages needed to contract the heart and other muscles in the body, assist in normal blood clotting, and helps to prevent high blood pressure and colon cancer (Sahra and Mwangi, 2008). Calcium has been proposed to help reduce cardiovascular disease (CVD) risk by decreasing intestinal absorption of lipids, increasing lipid excretion, lowering cholesterol levels in the blood, and promoting Calcium influx into cells (CRDRI, 2010). However, over the long term, inadequate Calcium intake causes osteopenia which if untreated can lead to osteoporosis. The risk of bone fractures also increases, especially in older individuals and Calcium deficiencies can also cause rickets, though it is more commonly associated with vitamin D deficiency (CRDRIV, 2010). Therefore, Calcium absorption is best when a person consumes no more than 500 mg at one time; Even though, the total and dietary Calcium intakes of 1,400 mg/day and higher were associated with higher rates of death from CVD and heart disease than intakes of 600–1,000 mg/day (Michaelsson *et al.*, 2013).

2.1.4. Iron deficiency

Iron is the main constituent in the synthesis of hemoglobin, which plays a vital role in the transport of oxygen and myoglobin (Moyo *et al.*, 2011). It is the most common nutritional deficiency, with approximately 2 billion people worldwide affected (Kramer and Kakuma, 2009). Infants and children under the age of five are at risk of developing iron deficiency anemia because of their increased requirements for rapid growth and diets that are often lacking in sufficient absorbable Iron (Britton *et al*, 2009). It can contribute to the formation of Iron-containing enzymes that are important for energy production, immune defense and thyroid function. The main causative factors of iron deficiency are poor iron content of the diet, low bioavailability of iron in the diet, or both. Food components such as phytate, tannins, and selected dietary fibers, which bind iron in the intestinal lumen, can impair iron absorption. Phytate has the greatest effect on iron status because many plant foods have high phytate content that can severely impair iron absorption (Mendoza *et al*., 2001). Complementary foods made from cereals are often low in iron content and contain significant quantities of Iron absorption inhibitors, phytic acid and condensed tannins (Pynaert, 2006). In Ethiopia the studies conducted so far are very limited and localized, making it difficult to estimate the exact prevalence of iron deficiency anemia in the country. Some data suggest that compared to other developing countries, Ethiopia has a relatively mild prevalence of anemia. In Ethiopian 17% women age 15- 49 are anemic and it is considered to be mild (Mulugeta *et al.*, 2015).

2.1.5. Zinc deficiency

Zinc is the fourth important micronutrient after vitamin A, Iron and iodine. It is found in all organs, tissues and body fluids, especially the bones and skeletal muscles (Islam *et al*., 2009). It plays vital role in cell division, protein synthesis and growth which makes infants, children, adolescents, and pregnant women at risk for an inadequate Zinc intake (Gardner *et al.*, 2005). Zinc contributes to reproduction, growth, taste, night vision, appetite, and the immune system functioning (Sahra and Mwangi, 2008). The main causes of Zinc deficiency are inadequate dietary Zinc intake, inhibitors of Zinc absorption and high Zinc losses due to diarrhea (Romana, 2003). It arises to a large extent from impaired bioavailability of dietary Zinc, largely attributable to the high phytic acid content of diets (WHO, 2000). In Ethiopia information on the prevalence of zinc deficiency is limited. However, in rural Sidma among pregnant women in the third trimester reported high prevalence's of inadequate dietary zinc intake (>99%) and low plasma zinc level (72%) (Abebe *et al.*, 2008).

2.1.6. Bioavailability

Bioavailability is the ability of the body to digest and absorb the mineral in the food consumed (Fekadu *et al*., 2013). It can be affected by many factors such as the presence of anti-nutrients, for example, phytates, oxalates, tannins and polyphenols in foods, a person's need, fiber, competition with other nutrients and acidity of intestinal environment (Norhaizan, and Norfaizadatul, 2009).

2.2.The Role of Complementary Foods in Improving Nutritional Status of Children

Complementary feeding is referred to as the process starting when breast milk alone is no longer adequate to meet the nutritional supplies of infants, and consequently other foods and liquids are needed, along with breast milk. This typically covers the period from 6 - 24 months of age, even though breastfeeding may continue to two years of age and beyond. This is a critical period of growth during which nutrient deficiencies and illnesses contribute globally to higher rates of undernutrition among children less than five years of age (WHO, 2015). Akinola *et al.*(2014) also reported that during the infancy period, nutritional requirements are at their highest, due to rapid physical growth as well as physiological, immunological and mental development. By the age of 6 months, infant has usually at least doubled his or her birth weight, and is becoming more active. Exclusive breastfeeding is no longer sufficient to meet all energy and nutrient needs by itself, and complementary foods should be introduced to make up the difference (Naylor and Morrow, 2001). Moreover, adequate nutrition and health care for children under the age of 5 years is fundamental to prevent malnutrition and child death (Zewditu *et al*., 2001; Ouedraogo *et al.*, 2008).

2.3.Main Ingredients of Complementary Foods in Ethiopian Context

Based on the Ethiopian Public Health Institute survey, nationally, most of the energy in the diet comes from carbohydrate. Carbohydrate contributes 67.2%, of the total energy intake in children. The carbohydrate contribution to energy intake was greater than 45% in all regions and target groups. Fat and protein contributions to total energy were 23% and 10.5%, respectively in children (Amha, 2013). According to Henry *et al.* (2015) in Ethiopia the majority of children consumed a diet deficient in energy and the nutrient density is insufficient to meet their requirements. An improvement of diet diversity is crucial for, both quality and quantity of their intakes. The main ingredients are complementary are cereals, legumes, fats, oil seeds products, fruit and vegetables:-

2.3.1. Cereals

Cereals are the most important source of food for the world population. Cereals are used as sources of nutrition for one-third of the world's population, especially in developing and underdeveloped nations underlining Sub-Saharan Africa and South-east Asia (Shewry, 2007).

Cereal products comprise more than 20%- 80% the average diet in the developed and developing countries. In addition, the crops are the main source of nutrients for weaning children in developing countries (Lyke *et al*., 2005). Cereals have great nutritional importance in preparation of complementary foods for children in developing countries like Ethiopia (Dicko *et al*., 2006). Among these cereals, Maize (*Zea mays L.*), is one of the most crucial and strategic cereal crops in Ethiopia and the developing world (Zhang *et al.*, 2012; CSA, 2014/2015). The use of quality protein maize in complementary food formulation replaced by white maize it gives better results and could alleviate the problem of protein and energy malnutrition, thereby reducing the mortality rate among infants (Ikujenlola *et al.,* 2014).

2.3.2. Legumes

Legumes play important roles in human nutrition since they are rich sources of protein, calories, certain minerals and vitamins (Iqbal *et al*., 2006). Although, legumes are deficient in sulfur containing amino acids, these enhance the protein content of cereal-based diets and contradicts may improve the nutritional status of the cereal based diets deficient in lysine and tryptophan (Fouad and Rehab, 2015). Legumes, including annual oilseeds, are high in protein, micronutrients, vitamins, minerals and plant fibers. Soybean is a good source of protein, fat and minerals as similar to other legume crops. It is generally known to be of good nutritional quality in terms of its protein quantity and quality (Iwe, 2003). The inclusion of soybean flour to QPM further boosted the recovery process since the lysine lacking in normal maize is sufficiently available in QPM and its addition to soybean further increased availability of the indispensable amino acids (Ikujenlola *et al.,* 2014).

2.3.3. Fats or oils seed flour products

Fat and oils are important in the diets of infants and young children, because they provide essential fatty acids, facilitate absorption of fat soluble vitamins, and enhances dietary energy density and sensory qualities. Dietary fats provide the infant and young child with energy, essential fatty acids and the fat soluble vitamins A, D, E and K. Fat not only provides energy in the diet, but also has an important role for promoting good health in humans WHO (2000). Total fat intake of infants and children's usually decreases with age as the contribution of breast milk to total dietary energy declines (Dewey and Brown, 2003). Oilseeds are important food crops and they can improve sensory attributes such as mouth feel. Those crops are soybean, cottonseed, rapeseed (canola), sunflower seed and peanut (Brien *et al.,* 2000). Oil seeds are the most important sources of fat in the human diet, in the demanding and competitive edible fats and oils marketplace. Soybean oil is very popular with rich value of Omega 3 and Omega 6 fatty acids. Soybean represents 55% of the total global production of oilseeds followed by rapeseed (14%), cottonseed (10%), peanut (8%), sunflower (9%), palm kernel (3%), and copra (1%) (Carrera *et al.*, 2011). Soybean has the highest fat content among the food samples (Onoja *et al*., 2014). Whereas, soybean contains about 18% of oil is amino acid profile of soy protein is excellent amongst plant proteins (Wilson, 2004).

2.3.4. Fruits and vegetables

Fruit and vegetables are important constituents of the diet and provide significant quantities of nutrients especially vitamins, minerals and fiber. Daily consumption of vegetables reduces the risk of cancer, heart disease, premature ageing, stress and fatigue primarily due to the integrated action of oxygen radical scavengers (Yu, 2016). Fruits and vegetables are important component of a healthy diet and, if consumed daily in sufficient amounts, could help prevent major diseases such as CVDs and certain cancers (Kaur *et al.,* 2016). According to WHO (2002) low fruit and vegetable intake is estimated to cause about 31% of ischemic heart disease and 11% of stroke worldwide. Overall, it is estimated that up to 2.7 million lives could potentially be saved each year if fruit and vegetable consumption was sufficiently increased. One such vegetable available is carrot, which is an excellent source of β-carotene and antioxidants (Kaur and Aggarwal, 2016).

2.4.Production of Quality Protein Maize, *Anchote,* Carrot and Soybean in Ethiopia

2.4.1. Production of maize (Z*ea mays L.*)

Maize is the first cultivated cereal in the world followed by (CSA, 2014/15). The kernel is used both for human consumption and or livestock feed (Iken and Amusa, 2010). In Ethiopia, maize is a leading cereal crop with main season production of 2.9 million tons in 2005/06 and accounting for 21.2% of major crops production (including pulses and oilseeds). Oromia region is the major maize producer which accounts for 61% of total production of maize in the country followed by Southern Nations Nationalities People's Region (SNNPR) (20%), (ATA, 2013). According to Monitoring African Food and Agriculture (MAFA) (2013) maize is an important food security crop in Ethiopia, with the cheapest caloric source among all major cereals. Currently, about 72,349,551.02Qt of Maize is produced in Ethiopia on 2,114,876.10 ha of land (CSA, 2014/15). In Jimma zone, 289,474 tons of maize was produced in 2007 /2008 production year (CSA, 2009). Quality protein maize has about twice the level of lysine and tryptophan than common maize (Ikujenlola, 2014).

2.4.2. Production of *Anchote* (*Coccinia abyssinica*)

Anchote is an endemic perennial trailing plant cultivated for its tuberous root in the South and Western parts of Ethiopia; there are about 10 species of *Coccinia* in Ethiopia; however, only *Coccinia abyssinica* is cultivated for human consumption (Abera, 1995 and Edwards, 1991). The total yield of *Anchote* is 150-180 quintals/hectare, which is in the range of the total yield of sweet potato, and potato (IAR, 1986). Among the major root and tuber crops, *Anchote* is a potential crop produced on nearly 3000 ha of land in West Wollega zone with a yield about 25,000 tones and it is used as food, cultural, social and economic crop for the farming communities (Anonymous, 2011; Habtamu, 2014).

2.4.3. Production of carrots

Carrots are not a major staple food in any part of the world due to low energy density; and considered a primary vegetable in many countries (Gocmen *et al*., 2015). China, Russia, and the United States are the top three producers of carrots globally, contributing almost 50% of the world carrot crop. Production and availability of carrots, and nearly all horticultural commodities that contain carotene, are increasing worldwide (Parvinder *et al*., 2015). The increase of world carrot production has also overtaken total world vegetable production (Rubatzky *et al.*, 1999). Currently, about 142,970.14Qt of carrot is produced in Ethiopia on 3,697.27 ha of land (CSA, 2014/15). Although the production trend is not consistent from year to year, the production of carrots has doubled between 2004/5 and 2010/11 (CSA, 2010/11) mainly due to increasing urbanization and the recognition of carrots as an income and nutrition source.

2.4.4. Production of soybean

Soybeans were first grown in Ethiopia in 1950 and it is an important grain legume crop and it is a leading plant source of dietary protein worldwide (Oelbermann and Echarte, 2011). In Ethiopia, soybean grower's manual was even published in Amharic, but trials were discontinued because yields were low. Trials began again in the late 1960s, and with the introduction of new high-yielding cultivars in the 1970s, new interest was generated. Throughout the 1970s Ethiopia produced 6,000 tons of soybeans a year, making it one of the top four African soybean producing countries. In 1981 about 2,000 hectares of land were under production by the State Farms Development Authority; this produced only 10 % of the soybeans required by the Ethiopian Public Nutrition institute (EPNI). As Presents, about 721,837.45Qt of soybean is produced in Ethiopia on 35,259.76 ha of land (CSA, 2014/15). Soybean protein quality has been the subject of intense investigation for several decades due to soybean's increasing importance as human food resource (Assefa, 2008).

2.5.Nutritional Composition of Quality Protein Maize, *Anchote,* Carrot and Soybean

2.5.1. Nutritional composition of maize

Maize in QPM is a staple food for an estimated 50% of the population and it remains the most important agricultural crop for over 70 million farm families worldwide (Nuss and Tanumihardjo, 2011). QPM is considered a bio fortified food, because its nutritional profile has been improved using conventional breeding techniques. This special type of maize possesses almost double the levels of lysine and tryptophan which are essential (amino acids) for human (Gupta *et al.,* 2010) (Table 1). Most African countries use quality protein maize for cereal based complementary foods replacing normal maize due to, essential amino acid cereals. There was little difference in the fat and crude protein of QPM and common maize varieties (Ikujenlola *et al*., 2014) (Table 2). According to Akumoa and Boateng (2002), the crude protein of QPM is not significant higher than that of common maize; however, it is better in terms of amino acids composition which is twice the maize (Ikujenlola *et al*., 2014).

Table 1: Essential amino acid composition of the common maize, QPM and soybean

Amino acid	**Common maize**	**Quality protein maize**	**Soybean**
Lysine	1.8	2.6	2.4
Tryptophan	0.5	1.1	0.6
Glycine	2.5	3.5	2.0
Cysteine	0.7	1.1	0.8
Valine	3.0	3.6	2.0
Methionine	0.9	1.2	0.6
Isoleucine	2.5	2.7	1.9
Leucine	8.8	3.3	3.6
Tryosine	2.1	2.7	1.3
Phenylanine	3.5	4.2	2.3
Aspartate	-	-	4.1
Glutamate	-	-	7.8
Serine	1.80	1.79	2.4
Histidine	2.0	2.0	1.0
Threonine	2.0	3.2	1.5
Alanine	-	-	1.8
Arginine	3.82	4.10	2.8
Hydroxyproline	-	-	0.1
Proline	1.15	1.09	2.0
TEAA	26.37	36.97	15.9
TNEAA	23.83	26.54	25.0
Total amino acid	50.02	63.5	40.4

Source: - (Carrera *et al.,* 2011; Ikujenlola *et al*., 2014)

2.5.2. Nutritional composition of *anchote*

Anchote an endemic tuber crop used as a food source in parts of Western Ethiopia (Addis, 2005). The crop has high nutritional value as well as potential for medicinal, economic and socio-cultural use (Abera, 1995). It is rich in carbohydrate and Calcium as compared to other root and tuber crops (Fikadu, 2013) (Table 2). Traditional medicinal practitioners use *Anchote* to treat different types of diseases such as diabetes, gonorrhea, tuberculosis, asthma and lowering cholesterol (Getahun, 1985). *Anchote* is a valuable food source when a crop is considered as a food source (Endashaw, 2007). According to Habtamu (2014), *anchote* helps in fast healing of broken/ fractured bones and displaced joints, as it contains high calcium content than other common and wide- spread root and tuber crops (Endashaw, 2007) in Table

2. Traditionally, it is believed that, *Anchote* makes lactating mothers and children healthier and stronger (Abera, 1995). The juice prepared from tubers of *Anchote* has saponin as an active substance and is used to treat Gonorrhea, Tuberculosis, and Tumor Cancer (Dawit and Estifanos, 1991). Therefore, addition of *Anchote* flour in to complementary foods advances the mineral contents (like calcium) of the final products.

2.5.3. Nutritional composition of carrot

Carrot is a globally important vegetable crop that is a source of important nutritional compounds (including pro-vitamin A) (Rakcejeva *et al.,* 2012). It is an important part of our diet and it provides not only the major dietary fiber component of nutritious as it contains appreciable amounts of vitamins B1, B2, B6, and B12 in Table 2. It also contains many important minerals and antioxidant compounds (Rashidi, 2011; Singh *et al.*, 2012). According to Ma *et al*.(2008) carrots have high nutrition, health care, medical values and it has the highest beta-carotene, a precursor of vitamin A content among human foods (Hsieh and Ko, 2008). According to Gocmen *et al*. (2015) the beta carotene content of carrot powder obtained by oven dried was 2000-4930µg/100g respectively (Table 2). Also carrot has been used in improvement of vitamin A contents of complementary foods (Onabanjo, 2009). Carrots contribute significantly to dietary vitamin A intake through β-carotene and modestly to other nutrients. Hence, addition of carrot for complementary food formulation improves beta carotene content of the porridge for children.

2.5.4. Nutritional composition of soybean

Soybean is an important grain legume crop and it is a leading plant source of dietary protein worldwide (Fageria, 2002). It is a good source of protein, fat and calcium content; it is often called the “miracle bean” because of its chemical composition and diverse applications for food, feed, and non-food uses. It has an exceptionally high content of both protein and fat (Kim, 2009). Soybean oil contains no cholesterol and has one of the lowest levels of saturated fat among vegetable oils. Soybean contains 29.6%-50.3% protein, 16% - 25% fats and oil; this implies that the crop is a very important source of food, oil, fodder and industrial material (MOARD, 2007) (Table 2). The amino acid profile of soy protein complements that of cereals (maize, sorghum, wheat and rice) in Table 2. Cereals, the main food staple consumed globally contains insufficient quantities of the amino acids lysine, tryptophan. In contrast, QPM has essential amino acids lacking in common maize; Soya protein is particularly valuable because it is a source of protein hence, blends of those crops improves the final product (Kim, 2009).

Table 2: Nutritional composition in quality protein maize, *Anchote*, carrot and soybean

N. composition	**C.maize**	**QPM**	***Anchote***	**Carrot**	**Soybean**
Protein (%)	9.0 [m]	9.72 [m]	2.67 [il]	1, [ef]	29.6-50.[p]
Fat (%)	4.6[m]	6.93 [n]	0.13 [il]	0.24 [g]	17-19d,[a]
Fiber (%)	2.2[m]	7.14 [m]	3.71 [il]	0.91 [e]	9.30a,4.8[d]
Ash (%)	1.2 [n]	1.52 [m]	1.33 [il]	0.73 [g]	4.87 [a]
CHO (%)	75 [n]	72.68[m]	10.42 [il]	9.44 [e]	30.16[a]
Energy(kcal)	378[m]	372.4[n]	53.48 [il]	41 [e]	446 [a]
Ca (mg)	65[o]	85.61[m]	115.7 [i]	33.0 [h]	277.0 [a]
Zn (mg)	11.5[n]	14.45[n]	2.03 [i]	0.2 [h]	4.89 [a]
Fe (mg)	7.0 [m]	3.3[n]	7.6 [i]	1.4 [k]	15.70 [a]
Phytate(mg)	1.2 [m]	117[o]	333.63[L]	61,[e k]	17.4 [b]
Tannin (mg)	9-11 [m]	-	102.36[L]	-	1.25 [b]
Beta-carotene mg	-	-	-	2-4.93[r]	-

Source:- ([d] Asiedu ,1989; [i] Fikadu, 2013; [n]EPHI, 1997; [o]FAO, 2009; [g]Ghavidel and Davoodi, 2011; [l]Habtamu, 2014; [m]Meseret, 2011; [j]Onabanjo 2009; [p]Onoja, 2014; [b]Rachel and Oluwamodupe ,2012 ; [r]Gocmen, 2015; [g]Rakcejeva *et al*., 2012; [k]Saeeda, 2009; [e]Shyamala and Jamuna, 2010; [a]Tinsley ,2009; [c]Ugwuona 2012; [h]USDA, 2002).

2.6.Anti-nutritional Factors of Quality Protein Maize, *Anchote,* Carrot and Soybean

Anti-nutritional factors are chemical compounds synthesized in natural food and / or feedstuffs by the normal metabolism of species and by different mechanisms (for example inactivation of some nutrients, decrease of the digestive process or metabolic utilization of food/feed) which exerts effect contrary to optimum nutrition (Sokrab and Ahmed, 2012). The anti-nutrients like trypsin inhibitors, phytic acid, saponins, heamagglutinins and tannins are some of the undesirable components in grains that could hinder utilization of protein and carbohydrate. Inactivation of these anti-nutrients is vital to enhance the nutritional quality and sensory acceptability of beans and in turn helps to effectively exploit their potential as food and animal feed. However, different processing methods such as soaking, blanching, germination and roasting are used to inactivate the anti-nutrients (Shimelis and Rakhshit, 2007).

2.6.1. Phytic acid

Phytate (also known as Inositol hexasphosphate, (InsP6) is the salt form of phytic acid which are found in plants, animals and soil. It is primarily present as a salt of the mono- and divalent cations K+, Mg^2+, and Ca^2+ and accumulates in the seeds during the ripening period. Phytate is regarded as the primary storage form of both phosphate and inositol in plant seeds and grains. In addition, phytate has been suggested to serve as a store of cations, of high energy phosphoryl groups and by chelating free iron, as a potent natural anti-oxidant (Mueller, 2001). Phytic acid (myoinositol hexaphosphate) present in most plant materials at high concentration in cereal and legumes. Phytate is found at low concentrations in roots, tubers and vegetables as phytate salt and it is the main phosphorus store in mature seeds (Reddy, 1989). Cereals contain approximately 1-2% phytic acid, and it can even rich 3-6%. In particular, cereals have a high content of phytate (Sandberg, 2002). Phytic acid binds some essential elements such as Iron, Calcium, Zinc, magnesium and phosphorus to form insoluble salts called phytate, which are not absorbed by the body and thereby reducing the bioavailability of these elements (Hussain, 2011; Vasagam and Rajkumar, 2011).

2.6.2. Condensed tannin

The word tannin is very old and reflects a traditional technology. Tanning was the word used in the scientific literature to describe the process of transforming raw animal hides or skins into durable, no putrescible leathers by using plant extracts from different plant parts (Mueller, 2001). Tannin is an astringent, bitter plant polyphenolic compound that either binds or precipitates proteins and various other organic compounds including amino acids and alkaloids (Redden, 2005). The term tannin refers to the use of tannins in tanning animal hides into leather; however, the term is widely applied to any large polyphenolic compound containing sufficient hydroxyls and other suitable groups to form strong complexes with proteins and other macromolecules (Muzquiz, 2007).

2.7.Functional properties of Flours

The functional properties of flours play important roles in the manufacturing of products (Baljeet *et al.,* 2014). It refers to those physical and chemical properties that influence the behavior of proteins in food systems during processing, storage, cooking and consumption as have been defined by Kinsella, (1976). The functional properties of protein are mainly dependent upon the imperative components of food systems including oil, water and air. Interaction of protein with water is an essential factor to determine the solubility behavior along with viscosity. Determining potential use of composite flours blends in food formulations, information regarding functional properties of blends are essential (Akubor and Ukwuru, 2013). The functional properties such as water and oil absorption capacity, bulk density, of flour are important to determine either the flour would be useful in development of food that affect processing applications, formulation, food quality, and acceptance of food products (Wu *et al.,* 2009).

2.7.1. Bulk density

Bulk density is a function of particle size, while particle size being inversely proportional to bulk density (Onimawo and Akubor, 2012). The differences in the particle size may be the cause of variations in bulk density of flours. The bulk density is generally affected by the particle size of the flour and it is very important in determining the packaging requirements and material handing in food processing industry (Ajanaku *et al.,* 2012). According to Chevanan *et al.* (2010) bulk density depends on the combined effects of interrelated factors such as the intensity of attractive inter-particle forces, particle size, and number of contact points. The decrease in packed bulk density could be because malting and fermentation tend to soften the seeds, thus making milling easier, with smaller particle sizes than un-malted grains, hence the reduction in bulk density. The low bulk density of flour would have higher nutrient density, since more flour can be packaged in the same given volume for preparation of complementary foods (Akubor, 2013).

2.7.2. Water absorption capacity

Water absorption of flour is dependent mainly on the amount and nature of constituents and to some extent on pH and nature of the protein (Gordon, 1993). Water absorption characteristic represents the ability of the product to associate with water under conditions when water is limiting such as dough and pastes (Akubor, 2013). Water absorption capacity of flour may depend on the higher polar amino acid residues of proteins that have an affinity for water molecules (Yusuf, 2008). The major chemical components that enhance the WAC of flours are proteins and carbohydrates. These constituents contain hydrophilic parts, such as polar or charged side chains (Lawal and Adebowale, 2004).

2.7.3. Oil Absorption capacity

Oil absorption capacity (OAC) is another important functional property since it plays an important role in enhancing the mouth feel while retaining the flavor of food products (Choonhahirun, 2010). Oils are essential components of all plants. However, commercial oil production only utilizes plants that accumulate large amounts of oil and are readily available. Currently, the largest source of commercial oils is oilseeds: the seeds of annual plants such as soybean, canola, rapeseed, cottonseed, sunflower and peanut (Carrera *et al.,* 2011).

2.7.4. Viscosity

According to Tizazu and Admasu (2009), viscosity is the most important determinant of energy density; complementary porridges prepared in low income countries are known with high viscosity which can limit the energy and nutrient need of children. Viscosity is important parameters for children during complementary foods preparation; it related to bulkiness due to starch gelatinization and proteins which are predominant nutrients in cereals root and tubers (Okpala *et al.*, 2013). Particularly, starch absorbs water on cooking forming a gelatinous mass while proteins will denature and exposed more hydrophilic sites that will take up more water. These mechanisms increase the viscosity of formulated food that contains significant amounts of starch and protein (Kanu *et al*., 2009). The viscosity of complementary foods preparing ranges had from (2,050 cP to 9,800 cP) for malted common maize and fortified malted quality protein maize (Victor *et al*., 2013). Children need a gradual transition from fluid to solid foods which allow the infants to develop feeding skills. Are early complementary feeding, the infant will reject very viscous foods by spitting them out. During the complementary feeding period, inadequate intake of energy and protein occurs because traditionally prepared complementary foods having high viscosity but low energy density and limit the infant's ability to eat enough and satisfy the need of its body growth (Keenan and Stapleton 2009).

2.8.Nutritional Functions of Complementary Food Compositions

2.8.1. Energy

Starch is likely to be a major constituent of many complimentary foods for older infants and young children. To ensure that its energy value is realized, this starch should be provided in a readily digestible form (Huffman and Martin 1994). Energy is required for tissue maintenance and growth, to generate heat and for physical activity. The factors limiting energy intake of an infant weaned with low energy weaning food gruels are the volume that the child can consume at one time and the frequency of feeding (WHO, 2000). According to (Iombor, 2009) dietary energy is consumed in the form of fat, carbohydrate and protein. When energy intake is less than the energy requirement of the individual, physical activity and/or rate of growth will be reduced. If the deficit continues, protein-energy malnutrition will develop; Low energy intake may also result in the metabolism of protein for energy and consequently lead to protein deficiency.

2.8.2. Proteins

Proteins are enzymes, hormones, membranes and blood transport molecules and intracellular matrix, fingernails and hair are all composed of proteins (Eschleman, 1984). It is the major functional and structural component of all the body cells. Protein, along with fats and carbohydrates, are essential in maintaining a balanced diet. Protein is used to rebuild muscle and other tissue in the body. It is the major source of energy and containing essential amino-acids (such as lysine, tryptophan, methionine, leucine, isoleucine and valine).To maintain cellular integrity, function and to ensure health and growth, an adequate supply of dietary protein is vital. Having enough protein in a diet is required in maintaining good muscle health and in addition to the building blocks of muscles is also essential for healthy immune, circulatory and respiratory systems. Inadequate intake of protein in developing countries has led to various forms of malnutrition in both children and adults (Okpala *et al.,* 2013).

2.8.3. Dietary fiber

Dietary fiber is the generic name for that component of the diet which is resistant to digestion by the endogenous secretions of the upper gastrointestinal tract. It includes polysaccharides other than starch and lignin (Allen and Ahluwalia, 1997). Dietary fiber has beneficial effects on bowel transit time, affects glucose and lipid metabolism, reduces the risk of colorectal cancer, stimulates bacterial metabolic activity, detoxifies the colon luminal content, and helps to maintain the equilibrium of the colon ecosystem as well as the integrity of the intestinal mucosa by acting as a pre-biotic. Dietary fiber fits the definition of a functional food in that it can affect one or more targeted function in the body in a positive manner (Lee, 2007). Indeed, excessive food fiber results in waste of nitrogen, energy, and minerals. The variations in chemical composition of fiber affect their ability to bind minerals during intestinal digestion of foods. Therefore, poor mineral utilization from certain types of fiber rich foods is probably due to the binding of minerals and electrolytes to fiber sources; in the complementary food the fiber will be best 5% (Vitali, 2008).

2.8.4. Beta carotene

Beta-carotene is one of many hundreds of food carotenoids, relatively only few of which have been studied in relation to their impact on human physiology (Ross, 1999). The biological activity of pro-vitamin A varies among different plant sources (fruits and vegetables). Carrots, mango, papaya, and melon contain large amounts of nutritionally active carotenoids (FAO, 1988). Those that can be converted to Vitamin A are called pro-vitamin A carotenoids. Beta-carotene has been considered virtually nontoxic because humans tolerate high dietary dosages without apparent harm (Diplock, 1995). Standard toxicological tests, including teratogenic, mutagenic, and carcinogenic assays, have been performed on beta-carotene without any evidence of harmful effects. The only documented biological effect of high beta-carotene intake has been discoloration of the skin related to hyper-carotenemia, but this occurs only at extremely high intake levels. Intakes as high as 180 mg per day have been given to humans for several months without observed adverse effects other than changes in skin color (Mathews, 1986). The vitamin A content of most staple diets can be significantly improved with the addition of a relatively small portion of plant foods rich in beta carotene content, the precursors of vitamin A (Igah, 2008).

2.9. Strategies for Improving Complementary Food in Ethiopia

Strategies to improve nutritional status and growth in children should include interventions to improve nutrition of early initiation of breastfeeding with exclusive breastfeeding for six months; promotion, protection, and support of continued breastfeeding along with appropriate complementary feeding from six months up to two years and beyond; and micronutrient supplementation, targeted fortification and food supplementation, when needed (WHO, 2013). The complementary foods developed based on cereal and starchy root have been associated with the incidence of protein energy malnutrition among the young infants (Inyang and Idoko, 2008). In Ethiopian, complementary food is composed of starchy cereals (maize, sorghum, and Teff). Maize is used as weaning food by complimenting with other legumes and or alone (Amankwah *et al*., 2009). All complementary foods produced from cereals are known to be deficient in certain essential amino acids which are required for the adequate growth and healthy living of infants (Gocmen *et al.,* 2015).

2.9.1. Quality protein maize

Ikujenlola *et al*. (2013) essential amino acids; lysine and tryptophan are in short supply in normal maize; however, a new hybrid called Quality Protein Maize (QPM) contains reasonable quantity of these essential amino acids. Apart from the problem of inadequate nutrients plaguing the complementary food produced from cereals, high dietary bulk and high viscosity are factors which affect the quantity of food a child could consume per meal; this invariably affects the quality of the nutrients available to the children (Sodipo and Fashakin 2011). Quality protein maize is used by most African mothers for complementary food for under age of five children replacing this common maize due to its low nutrient content (Olakojo *et al*., 2007).

Complementary food formulation using maize with amaranth and chickpea improves nutrient contents of the diet (Alemselam *et al*. (2015). Similarly, Beruk *et al*. (2015) complementary food developed from quality protein maize based porridge with chick pea, orange flashed sweet potato and Teff improved the nutrient content of the final product. Akinola *et al*. (2014) formulation of nutritionally adequate complementary foods prepared from maize, carrot, millet, guinea corn, soybeans and groundnut. Victor *et al*. (2013) complementary food developed from quality protein maize with pumpkin flour it improves physico-chemical properties of final product. Weaning food developed from quality protein maize with soybean improved the nutrient content of foods (Meseret, 2011). Complementary food that will support growth and maintain good healthy living must contain adequate nutrients and be of low viscosity (Ikujenlola *et al.*, 2014). Complementary food preparation in developing countries contain high levels of carbohydrate with very low or no proteins due to the high cost of protein rich foods. Therefore, it needs other sources of protein content such as soybean.

2.9.2. Soybean

Legumes such as soybean, groundnut and cowpea are rich in quality protein, oil and minerals. Soybean is generally known to be of good nutritional quality in terms of its protein quantity and quality (Iwe, 2003). Its lysine content complements amino acid deficiency in cereal while the methionine in cereal complements deficiency in the legumes. Therefore, the blends of legume with cereals crops give high-quality protein complementary mixtures. In order to combat PEM efficiently, a low-cost weaning food that is high in protein and dense in energy is a desirable substitute for expensive imported weaning foods. Soybean is increasingly being used as a high source of protein to upgrade the protein level children's diet (Omueti *et al.*, 2009). According to Onoja *et al*. (2014) who reported that complementary food formulated from soybean with sorghum and plantain improved the protein content of the final product. Similarly, Akinola *et al*. (2014) expressed that complementary food developed from different cereal and legumes and root crops supplemented by soybean improved the protein content of the final products.

2.9.3. Carrot

Carrot is one of the most important resources of dietary carotenoids (Singh *et al.*, 2012) .The dried carrot pomace has carotene in the range of 9879 to 11570µg Req/per 100 g, respectively (Upadhyay *et al.*, 2008). Therefore, the use of carrot powder for complementary food by mixing with other cereals, pulses and root and tuber crops, it improves the beta carotene content of children foods. According to Akinola *et al.*(2014) who reported that complementary food prepared from carrot with other crops like maize, soybean and ground nut mixed it improves the beta carotene content of the product.

2.9.4. *Anchote*

Anchote is a valuable food source; According to, Habtamu (2014) in Jimma zone. *Anchote* is used for different foods types and it helps in fast mending of broken/ fractured bones and displaced joints, as it contains high calcium than other common and wide spread root and tuber crops (Endashaw, 2007). Therefore, supplementation of *Anchote* tuber flours with other cereals and pulses may improves the calcium content of complementary foods. However, there is no information to data on the use Anchote in complementary foods. The use of QPM, anchote, carrot and soybean blends in complementary food formulation gave better results and could alleviate the problem of protein, calcium and energy malnutrition, thereby reducing the mortality rate among children (Ikujenlola *et al.,* 2014).

2.10. Formulation of Complementary Foods of High Nutritive Value

According to Beruk *et al*. (2015) and Yewelsew (2006), in the developments complementary consider for basic principles such as: high nutritional value to supplement breastfeeding, locally acceptable, low price, and use of local food items afforded is consideration. The complementary foods are often low in nutritional quality and given insufficient amounts, when given too early or too frequently, they replace breast milk (Villapando, 2000). Promotion of diet diversity and adequate quantity, including increased consumption of animal products, legumes, fruits and vegetables to increase intakes of protein, vitamin A, Calcium, Zinc, Iron and folate common diet. This would also promote consumption of foods that are good sources of folate, vitamin C and other micronutrients that are likely to be low in the reported diets. Furthermore, exploring alternatives for improving nutrient density of complementary foods through local production of nutrient rich complementary foods should be applied (Amha, 2013). Adoption of recommended breastfeeding and complementary feeding practices and access to the appropriate quality and quantity of foods are essential components of optimal nutrition for infants and young children (Lutter and Rivera, 2011). However, commercial complementary food may not be available to most low-income households in developing countries. Recommending commercial weaning foods may not be feasible due to limited income and inaccessibility.

2.11. Processing to Boost the Nutritional and Sensory Quality of Complementary Foods

Anti-nutritional factors can be eliminated or reduced by cooking or with other simple technologies (Urbano *et al.*, 1995). Also processing will improve the nutritive utilization of protein and it reduces anti-nutritional content of foods. Most ANFs are heat-labile, such as a-galactosides, protease inhibitors and lectins, so cooking would reduce any potential effects before consumption. On the other hand, tannins, phytic acids and saponins are heat-stable, but can be reduced by de-hulling, soaking, germination and/or fermentation (Muzquiz and Wood, 2007). Hence, processing methods such as soaking, germination, fermentation and cooking have been reported by many researchers to alleviate the effect of ANFs and to improve the nutritional value of cereals and legume seeds (Sokrab *et al.,* 2012). Mostly, cooking and germination play an important role as they influence the bio-availability and utilization of nutrients and also improve palatability which incidentally may result in enhancing the digestibility and nutritive value of the products (Ramakrishna *et al.,* 2006). Traditional processing techniques include (i) non-heat processing methods such as, soaking, germination, de-hulling (ii) heat processing methods such as, blanching, roasting and cooking:-

2.11.1. Soaking

Soaking is a traditional technological treatment that is often used by mothers to prepare complementary foods at home. Moreover, it can be a simple prolongation of the obligatory washing of the seeds and can also have other advantages, such as facilitating dehulling or swelling of the seeds (Elmaki *et al.,* 2007). Soaking in water allows the seeds to absorb water, to decrease and eliminate anti-nutritional factors in different crops and this process also reduces the anti-nutritional factors such as protease enzyme inhibitor, phytic acid, and certain minerals. Soaking improve protein content of legumes, insoluble dietary fiber (IDF), total dietary fiber (TDF), Ca, Cu, Mn and P. It was reducing ash and mineral contents such as (Fe, K, Mg and Zn) (Wang *et al.,* 2008; Oladele *et al.,* 2009).

2.11.2. Germination

Germination is one of the most common techniques used to reduce most of the anti-nutritional factors (Hussain *et al.,* 2011). It is a simple biochemical enrichment tool to enhance the palatability, which may result in increasing the digestibility and nutritive value its indispensable food ingredients. According to Inyang and Zakari (2008), the increase in protein on germination of corn seed is due to mobilization of storage nitrogen in the grains. The level of ANFs, trypsin inhibitory activity, phytates, tannins and total polyphenols reduced considerably during germination (Afify *et al.*, 2011). It has also been found to decrease the levels of ANFs present in cereals and maximize the levels of some utilizable nutrients and reduce the bulk density and viscosity of the product (Meseret, 2011; Shakuntala and Naik, 2011).

2.11.3. De-hulling

De-hulling has been reported to reduce tannins, soluble dietary fiber (SDF), insoluble dietary (IDF), total dietary fiber (TDF), Ca, Cu, Fe, Mg and Mn and increases in crude protein, starch, K, P, phytic acid of legumes (Wang *et al.,* 2008). De-hulling has been reported to improve the palatability and taste of some legume seeds (Wang *et al.,* 2009). De-hulling during weaning food preparation has also significant effect on the composition of the food to be prepared. It is used to remove the bran and/or germ from cereals, which in turn may also reduce their phytate content when it is localized in the outer aleurone layer (e.g., rice, sorghum, and wheat) or in the germ (i.e., maize). Hence, bioavailability of Iron, Zinc, and calcium may be enhanced, although the content of minerals and some vitamins, particularly the B-vitamins of such de-hulled products can be reduced (Gibson and Hotz, 2001). De-husking causes a reduction in the levels of some anti-nutrients minerals and lipid while a carbohydrate increases and de-husking increases protein contents in legumes (Oseni, 2011).

2.11.4. Roasting

Heat treatment significantly improves the protein quality, color, extends shelf life, enhances flavor in pulses by destruction or inactivation of heat labile anti-nutritional factors of cereals and legumes (Kavitha and Parimalavalli, 2014). Moreover, roasting of grains lead to denaturation of proteins, thus improving their digestibility (Boye *et al*., 2010; Wang *et al.*, 2008). Roasting is widely used to produce pre-gelatinized flours and to facilitate bran removal. The accumulation of heat to legumes by roasting and toasting renders the husks easier to be removed since they become brittle and subsequently crack. When these methods are applied to moistened grains, the cotyledons have a tendency to shrink more than the husk, resulting in the husk being loosened from the cotyledon (Fasoyiro *et al.,* 2010). In addition to facilitating husk removal, heating can be effective in destroying toxic factors present in legumes (Sokrab and Ahmed 2012). Heating legumes (soybean) also improves protein quality sensory quality of the products such as color and flavor (Hassan *et al.,* 2006). The process also enhances the acceptability of porridge made from roasted flour, because of that dextrinization of starches by starch breakdown (Mensah and Tomkins, 2003).

2.12. Recommended Dietary Allowance for under five age

The Recommended Dietary Allowance (RDA) is an estimate of the minimum daily average dietary intake level that meets the nutrient requirements of nearly all 97 to 98 percent healthy individuals in a particular life stage. The RDA is intended to be used as a goal for daily intake by individuals as this value estimates an intake level that has a high probability of meeting the requirement of about 97.5 percent of under-five age (Food and Nutrition Board, 2005).

Table 3: Recommended Dietary Allowances for children under five years of age

Nutrients	RDA
Protein (g)	> 18
Fat (g)	9 to 25
Fiber (g)	<5
Energy (kcal)	370-420
Calcium (mg)	>500
Iron (mg)	5-10
Zinc (mg)	3
B-carotene (µg/RAE)	>800
Ash (g)	1-3
Carbohydrate (g)	>58

Source: - (WHO/ FAO, 2004; CODEX CAC/GL 08. 1991, FAO/WHO, 2012; Ayo *et al*., 2011, FNB, 2005, Faber *et al*., 2008)
(2 µg of beta-carotene equal to 1 µg RAE, UNICEF, 2016).

2.13. D-optimal Mixture Design in Food Formulation

Mixture experimental designs are suitable for food products that require a composition or a blend of main ingredients, since proportions of the ingredients in the mixture, and their levels are dependent on each other, and the sum of all components is always 1 or 100% (Hare, 1974). D-optimal mixture design (DMD) is an effective technique for optimizing complex processes (Caroline *et al.*, 2007). Optimization can be defined as the choice of the best alternative starting from a specified set of possibilities. The ingredients are the independent variables or factors and the dependent variable or response is the factor to be optimized (maximized or minimized).

3. MATERIALS AND METHODS

Description of the Study Area

The laboratory experiment was conducted at Jimma University College of Agriculture and Veterinary Medicine (JUCAVM) in Post-harvest Management laboratory and animal nutrition laboratory, Ethiopia Public Health Institute (EPHI) nutrition laboratory and Addis Ababa University, Science and Technology Institute Chemical and Bio Engineering, Department in food chemistry laboratory (AAiT).

Sample Collection

Samples were collected from different sources Quality protein maize (BHQPY 545) was obtained from Omonada Woreda Doyoyaya Kebele, From farmer training center distributed by nutrition for maize in Ethiopia (NUME) project, *Anchote* local variety was collected from Bako Research Center (BRC), Carrot was obtained from local market in Jimma town and Soybean (Afgat) variety was obtained from Jimma Agriculture and Research Center (JARC). All chemicals used for this study were of analytical grade.

QPM *Anchote* Carrot Soybean

Figure 1: Raw materials used in the complementary food formulation

3.1. Sample preparation

Each grain and vegetables were processed for chemical analysis following standard procedures.

3.1.1. Preparation of quality protein maize flour

Flour samples of quality protein maize were prepared according to the method developed by Ahima, (2011). Twenty kilo grams of quality protein maize grains were cleaned and sorted. Small, broken and immature grains, dust, sand, stones, and other foreign materials were manually removed. The cleaned QPM was washed with distilled water repeatedly and soaked in a volume of water three times the weight of seed (1:3, w/v) for 24 hrs at room temperature. Soaked quality protein maize grains were germinated for 72 hrs at room temperature ($23\pm5^{o}C$) and relative humidity (52-55%). Germinated grain was dried in oven (LEICESTER LE67 5FT, England) at a temperature of $60^{o}C$ till it reaches to the moisture content 11-12 %. Dried germinated quality protein maize was milled by disk miller (D-6072 Dreich, and West Germany). Finally, the flour samples were packed in polythene plastic bags and stored at room temperature in dry place two months for analysis.

3.1.2. Preparation of *anchote* flour

Anchote flour was prepared according to the method established by Habtamu, (2014). *Anchote* tuber samples were washed in tap water to remove soil and other foreign materials. After washing, tuber samples were peeled manually with repeated washing and boiled for about three hours. The cooked tuber samples were then sliced to uniform thickness of 5 mm using a stainless steel knife. The sliced samples were dried in oven (LEICESTER LE67 5FT, England) at 60°C for 72 hours. Anchote samples were milled into fine powder using on electric grinder (D-6072 Dreich,West Germany) until to pass through 0.5 mm mesh size sieve, and finally packed into polyethylene plastic bags. The flour samples were kept in dry place at room temperature until required for further analysis.

3.1.3. Preparation of carrot flour

Carrot flour was prepared following the method developed by (Woolfe, 1992). Carrots were washed under running tap water, hand peeled, washed repeated, and then sliced into 2 to 3 cm thickness. After slicing, samples were strained and spread over trays and dried in an oven (LEICESTER LE67 5FT, England) at the temperature of $50^{o}C$ for 12 hr. The drying process continued till the moisture content of the sample was reduced to about 11% following the procedure of Kumar, (2011). Finally, the dried samples was milled into fine powder using miller (D-6072 Dreich, West Germany) to pass through 0.5 mm mesh size. The flour was packed into polyethylene plastic bags and carefully covered by black plastics to protect the samples from light exposure. The flour samples were kept in dry place at room temperature until required for analysis.

3.1.4. Preparation of soybean flour

Soybean flour was prepared using the method established by Assefa, (2008). The soybean grains were sorted to remove defective grains, stones, soil, and other debris. Clean soybean seeds were blanched at 100^0C for 30 minutes (to inactivate lipoxygenase enzymes), the seed coat was removed and was placed in cold water and agitating with hand and de-hulled repeatedly washed. Cleaned soybean cotyledons seeds were dried in an oven (LEICESTER LE67 5FT, England) at a temperature of 60°C for 16 hr. The dried beans were then roasted for 8 min at $110\text{-}130^o$C to improve beany flavors bioavailability of nutrients (protein and minerals), sensory quality and to reduce anti- nutritional factors of the grains. The beans were then grinded (D-6072 Dreich, West Germany) and sieved using 0.5mm mesh size to produce finer flour, and finally stored in a container for further laboratory analysis.

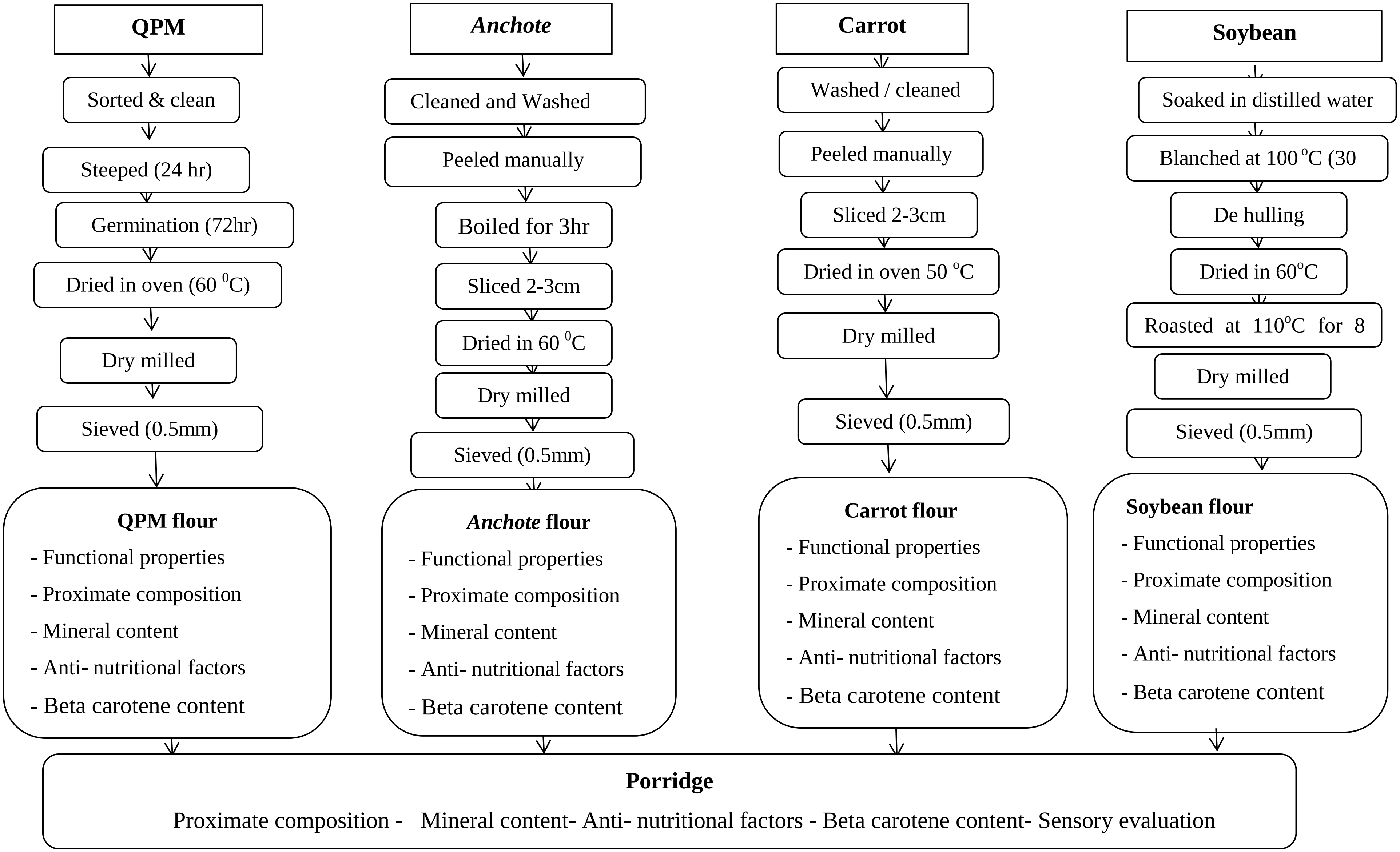


Figure 2: Flow diagram for the experimental framework and flour preparation of the four ingredients

3.2. Preparation and Formulation of Quality Protein Maize Based Complementary Food

Complementary food preparation for young children is undertaken using Cameron and Hofvander, (1983) method with minor modification. Briefly, in this work, to formulate the complementary food the following components were included based on literature and preliminary study conducted. Maize (common white seeded variety) is a staple food in developing countries including Ethiopia. For instance in Jimma zone (study area), mothers feed their children diets mainly prepared from maize a staple food. To fill this gap QPM was selected as the main ingredient as a source of missing amino acid (lysine and tryptophan). *Anchote* tuber is used as a source of calcium traditionally it is used as a therapeutic food to heal broken bones strengthens children during their growth. As a source of pro-vitamin A, carrot was considered due to its market availability and easily grown by farmers in home-steads. Soybean was included of its high protein fat, minerals as a source of fat, minerals and beta-carotene source.

3.3. Experimental design and treatment combinations

3.3.1. Experimental design

The treatment combinations were designed using computer generated D-Optimal mixture design (Design-Expert®, version 8). A total formulation of 17 runs (Table 5). Therefore, using components balance and equating simultaneous equations, blend ratios of QPM (45-85%), *Anchote* (10-20%), carrot (5 - 15%) and soybean (0-20%) were used to set up the experiment in Table 4. Contour plots were constructed based upon three components ratio to produce better quality complementary foods and one component holding constant less importance of for all response variables.

Table 4: The upper limit and lower limit of each ingredient in composite flour (ratio)

Component	**Lower limit**	**Upper limit**
QPM	0.45	0.85
Anchote	0.10	0.20
Carrot	0.05	0.15
Soybean	0	0.20

Table 5: Blend formulation of QPM-based complementary food samples (ratio)

Formulation number	**Germinated/QPM maize flour**	**Anchote flour**	**Carrot flour**	**Soybean flour**
CF1	0.85	0.100	0.050	0.00
CF2	0.45	0.200	0.150	0.20
CF3	0.65	0.100	0.050	0.20
CF4	0.55	0.200	0.050	0.20
CF5	0.75	0.200	0.050	0.00
CF6	0.55	0.100	0.150	0.20
CF7	0.75	0.100	0.150	0.00
CF8	0.65	0.200	0.150	0.00
CF9	0.65	0.150	0.100	0.10
CF10	0.75	0.125	0.075	0.05
CF11	0.55	0.175	0.125	0.15
CF12	0.65	0.125	0.075	0.15
CF13	0.60	0.175	0.075	0.15
CF14	0.70	0.175	0.075	0.05
CF15	0.60	0.125	0.125	0.15
CF16	0.70	0.125	0.125	0.05
CF17	0.65	0.175	0.125	0.05

CF= Complementary Food

3.4.Functional Properties of Composite Flours

3.4.1. Bulk density

Bulk density was determined as indicated in Adeleke and Odedeji (2010). Fifty gram flour sample was placed into a 100 mL measuring cylinder. The cylinder was tapped several times on a laboratory bench to a content volume. The volume of sample is recorded and bulk density was calculated using

$$Bulkdensity\left({}^{g}/_{cm^3}\right) = \frac{weight\ of sample}{volume\ of sample\ after\ tapping} \quad \text{Equation (1)}$$

3.4.2. Water Absorption Capacity

Water Absorption Capacity (WAC):- were determined using method of (Adebowale *et al.*, 2005). Ten mL of distilled water was added to one g of sample in a 15mL test tube. The suspension obtained was there after centrifuged at 3500 rpm for 30 minutes, and the supernatant was decanted and measured into 10 ml graduated cylinder. The water absorbed by the flour was calculated as the difference between the initial volume of the sample and the volume of the supernatant (Water absorption =10 ml- final reading from the cylinder) (Centrifuge model 800-1) for 30 min and the volume of the supernatant was measured in a 15mL graduated cylinder.

3.4.3. Oil Absorption Capacity (OAC)

Oil Absorption Capacity (OAC):- was determined using method of (Adebowale *et al.*, 2005). Ten mL of oil was added to one g of sample in a 15mL test tube. The suspension obtained was there after centrifuged at 3500 rpm for 30 minutes, and the supernatant was decanted and measured into 10 ml graduated cylinder. The oil absorbed by the flour was calculated as the difference between the initial volume of the sample and the volume of the supernatant (Oil absorption =10 ml- final reading from the cylinder). Centrifuge for 30 min and the volume of the supernatant were measured in a 15mL graduated cylinder.

3.5. Porridge Preparation

Porridge was prepared according to Onabanjo *et al.* (2009) from each seventeen composite flour samples. Three hundred gram of each composite flour was mixed with 450 mL of boiled water and cooked for 20 min at $90\pm2^{o}C$ with continuous stirring to avoid coagulation and formulation of flours. After 20 min of cooking, the beaker with porridge was removed from the hot plate, cooled and used for required analyses.

Various response variables were measured and data were collected at different level of the experiment. Data were collected on functional properties of flour and proximate composition, β-carotene content, mineral content, anti-nutritional factors, viscosity, and sensory evaluation of porridge developed from different proportion of quality protein maize, *Anchote*, and carrot and soybean flour and composite flour used to prepare porridge.

3.6. Viscosity

The viscosity of cooked complementary porridge was determined by following methodology of according to Mbata *et al.* (2009). Each ingredient and composite flour with 100g was prepared with 180mL of distilled water were boiled. The flour mixed with the boiled water in to beaker then was cooked for 20 min at 90 ±2°C with continuous stirring to avoid coagulation and formation flours. After 20 min, the samples were allowed to cool to 40°C. Then viscosity was set on the digital Vibro-Viscometer (SV-10, Germany) read. Viscosities of the cooked porridge were measured in viscometer and the values recorded Pascal /seconds ($Pa.s^{-1}$.) was used. The dry matter values were compared with consistency and viscometer measurement.

3.7. Proximate composition Analysis

Proximate composition of each ingredient flour and porridge prepared from different levels of the composite flour was determined. All analyses were performed in duplicate.

3.7.1. Determination of moisture content

Moisture content of the composite flour, individual flour and porridge samples were determined by dry air oven method according to AOAC (2011) method 925.10. The petri dish was dried at 130 ± 3°C for 1 hr. and placed in desiccator and weighed after cooling for 30 minute. About 2 g of porridge flour was weighed and placed on pre-dried dish. Sample then placed in the oven uncovered (LEICESTER LE67 5FT, England) at 102°C ± 3°C for 1 hr. The sample containing dish was covered and transferred to a desiccator and weighed once its temperature equilibrated to room temperature. The same drying and reweighing repeated for 2-3 times until the sample showed no change in weight. Then, the moisture content was estimated using

$$\text{Moisture (\%)} = \frac{(\mathrm{M_{intial}} - \mathrm{M_{dried}})}{\mathrm{M_{intial}}} \mathrm{x}100\% \quad \text{Equation (2)}$$

Where:-

M_{initial}= moisture content before drying

M_{dried}= moisture content after drying

3.7.2. Determination of total ash

Ash content of the porridge and ingredient flour samples were determined by (AOAC, 2011), method 923.03. The crucibles were cleaned and dried at 120°C and ignited at 550°C at furnace (Model SX-5-12, China) for 30 min. The crucibles were removed from the furnace and were placed in desiccators to cool down at room temperature. The mass of crucibles were measured by analytical balance and weigh recorded as (M1). About 2 g of the porridge and ingredients flour samples were weighed in to crucibles (M2). The sample was dried at 120°C for 1 hr in drying oven (LEICESTER LE67 5FT, England). The sample was placed at furnace at about 550°C until free from carbon and the residues appear grayish white (for about 8 hrs). The sample was removed from the furnace and placed in the desiccator followed by weighing the mass and recorded as (M3):- and applying a simple formula

$$\text{Total ash}(\%) = \left(\frac{\text{M3}-\text{M1}}{\text{M2}-\text{M1}}\right)\text{x}100 \qquad \text{Equation (3)}$$

Where;

M1 = Weight of empty crucible

M2 = Weight of crucible + sample before ashing

M3 = Weight of crucible + sample after ashing

3.7.3. Determination of crude protein

The protein content was calculated from the nitrogen content of the porridge and ingredient flour is determined by Kjeldahl method involving digestion, distillation, and titration (AOAC, 2005) method 988.05. About 0.3 gm of sample was measured by analytical balance (Model: ABJ220-4M, Australia), one g of catalyst mixture of K_2SO_4 and $CuSO_4$ and 5 mL of sulfuric acid added to each digestion flask (Kjeldahl flask KF250,German) which contain the mixture of sample and catalysts. The solution (0.3 gm of sample + 1 gm of K_2SO_4 and copper sulfate + 5 mL of H_2SO_4) was immediately placed in digestion flask at about 420 °C for 3 - 4 hrs.

until the solution becomes clear. The digested sample was then transferred into the distillation apparatus and 25 mL of 40 % (w/v) NaOH was continually added to the digested sample until the solution turned cloudy which indicated that the solution had become alkaline. The mixtures were then steam distilled and the liberated ammonia was collected into a 200 mL conical flask containing 25 mL of 4 % boric acid plus mixed methyl red indicator solution. Next distillation was carried out into the boric acid solution in the receiver flask with the delivery tube below the acid level. As the distillation was going on, the pink color solution of the receiver flask turned green indicating the presence of ammonia. Distillation was continued until the content of the flask was reaching the required amount. The green color solution was then titrated against 0.1N HCl solutions. At the end point, the green color turned to red pink color, which indicated that, all the nitrogen trapped as ammonium borate have been removed as ammonium chloride. The distillate was titrated with standardized 0.1N sulfuric acid to a reddish color. Ultimately the percentage of nitrogen content was estimated using the following formula

$$\text{Total nitrogen} = \frac{(\mathrm{T}-\mathrm{B})\mathrm{x}\ \mathrm{N}\ \mathrm{x}14.007\ \mathrm{x}\ 100}{\mathrm{w}} \quad \text{Equation (4)}$$

Where:

T= Volume in ml of the standard 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 sulphuric acid

W= Weight in grams of the test material

Crude protein = 6.25 * total nitrogen

3.7.4. Determination of total crude fat

Crude fat was determined by extracting the fat using diethyl ether which has ability to selectively extract the fat components of the food matrix by ether extraction according to AOAC (2005) method 2003.06. The aluminum cups used for fat collection were well cleaned and incinerated for 30 min at 105 ^{o}C. The aluminum cups were cooled in desiccators. The weight of six containers was recorded (W2). Simultaneously, about 1.5 gm of oven dried sample was weighed (W1) and added to filter paper (Whatman #1). It was put into a thimble and covered with cotton both at the bottom and upper of the thimble. Six thimbles with measured sample placed in a Soxhlet extractor (model: SZC-C fat determinate, china) by attaching them with the magnetic ring to hang the thimble to the extraction chamber. The extraction aluminum cups were arranged in correct order and 30 mL of diethyl ether solvent added into fat collecting aluminum cups. The aluminum cups were covered and tightly clamped after placing them on to the extractor. The sample contained in the thimble was extracted in a Soxhlet extraction apparatus for 1:30 hrs. Then they were heated and vapors of the solvent were condensed by running cold water through condenser of the extractor. The first phase of this method was soaking the folded samples into the solvent for 30 minutes. Following to the successful completion of the soaking time, for about 45 minutes extraction processes were continued. The extract transferred from the extraction flasks into the pre-weighed aluminum cups with continuous rinsing with the solvent. During all this time, the condenser ensures that any solvent vapor cools, and drips back down into the chamber housing the solid material. After extraction, the ether was allowed to cool for 15 minutes in the Soxhlet extractor, and finally, the aluminum cups which hold extract were transferred in to the oven for at least 30 minutes at 105 ^{o}C to vaporize any non-fat compounds, including water. When the drying period is over the cups and extracts were removed from the oven and transferred into a desiccator for cooling. Finally, the cups and its contents were recorded (W2) immediately after taken out of the desiccator and the crude fat percentages were calculated as follows

$$\text{Crude fat } (\%) = \frac{\text{W2} - \text{W1}}{\text{W3}} 100 \qquad \text{Equation (5)}$$

Where:

W_1= Weight of extraction flask before extraction

W_2 = Weight of extraction flask after extraction

W_3 = Weight of sample

3.7.5. Determination of crude fiber

The crude fiber was determined by the non-enzymatic gravimetric method of AOAC, (2005), method, 922.16. About 1.5 g food samples was placed into 600 mL beaker and 200 mL of

1.25% H_2SO4 was added to each beaker and allowed to boil for 30 min by rotating and stirring. During boiling, the level was kept constant by addition of hot distilled water. After 30 min, 20 mL of 28% potassium hydroxide solution was added in to each beaker and again allowed to boil for another 30 min. The level was still kept constant by addition of hot distilled water. The solution in each beaker was then filtered through crucibles containing sand filter by placing each of them. During filtration the sample was washed with hot distilled water. The final residue was washed with 1% H_2SO_4 solution, hot distilled water, 1% NaOH solution, 1% H_2SO_4, hot distilled water and finally with acetone. Each of the pre-weighed crucibles with their contents was dried for 2hr. at 130°C in the oven (Memmert 854 schwabach, West Germen) and cooled in desiccators and weighed (M1). Then again they were ashed for 30 min at 550°C in furnace (Stuart 2416, UK) and were cooled in desiccators. Finally, the mass of each crucible was weighed (M2) to subtract ash from fiber. The crude fiber was calculated

$$\text{Crude Fiber (\%)} = \frac{\text{M2} - \text{M1}}{\text{Weight of sample}} 100 \qquad \text{Equation (6)}$$

Where,

M_1 = mass of crucible and residue before ignition

M_2 = mass of crucible and residue after ignition

M_3 = Weight of sample

3.7.6. Determination of carbohydrates

According to Otitoju (2009) the utilizable carbohydrate content of the composite flour and individual ingredient was determined by subtracting the summed up percentage compositions of moisture, ash, protein, fat and fiber content from 100 g of the sample by using the following mathematical expression:-

CHO= 100 %-(Moisture% + Ash % + Protein % Fat%+ Fiber %)

3.7.7. Determination of calorific value/gross energy

Gross energy was determined by calculation from fat, carbohydrate and protein content using the Atwater's conversion factor; 4.0 kcal/g for protein, 9.0 kcal/100g fat, 4.0 kcal/g for carbohydrate (Iombor *et al.,* 2009).

The energy content of each ingredient and composite flour samples were calculated using:-

$$\text{Energy value} = (P^{*} 4) + (F^{*} 9) + (CHO^{*} 4) \text{ in kcal/100g of the sample} \qquad \text{Equation (7)}$$

Where;

P = Protein content (%).

F = Fat content (%).

CHO = Available total carbohydrate (%)

3.7.8. Determination of β-Carotene

Beta (β) - Carotene was determined by using the method of Sadler (1990). One gram of each sample was mixed with 1g of $CaCl_2.2H_2O$ and 50 mL extraction solvent (50 % n-hexane, 25 % acetone, and 25 % ethanol) and shaken at five minute interval for 30 min at 4 ± 1^oC refrigeration. Again 15 mL of deionized water was added and the solution was frequently shaken at five minute interval for 15 min at the same temperature. The organic phase, containing the ß-carotenoids was separated from the water phase, using a separators funnel, and filtered using Whatman filter paper No.1. The extraction procedure was carried out under subdued light to avoid degradation of carotenoids by light. β -carotene was estimated from a standard curve of beta carotene standard product of Sigma Aldrich dissolved in the same solvent combination. Calibration curve was constructed using a series of working solutions with varying B-carotene concentrations of 1,2,3,4,5,6,7,8,9,10,11, and 20µg/mL. The standard solutions were taken into the test tubes and the volume of each test tube was adjusted to 10 mL of β -carotene standard calibration curve (concentration Vs absorbance) was prepared using Beta-carotene standard and determined using double beam UV-Vis spectrophotometer (T80, China) at 450nm wavelength. Finally, the β-carotene of each sample was calculated using the standard calibration curve**.**

3.8. Determination of Anti-nutritional Factors

3.8.1. Phytate determination

Phytate was determined by the method of Vaintraub and Lapteva (1988). About 60mg of ingredient and composite porridge sample were extracted with 10 mL 0.2N HCl in methanol using a mechanical shaker (Eberbach) for an hour at an ambient temperature and centrifuged at 3000rpm for 30 minute. The clear supernatant was used for phytate estimation. A 2mL of Wade reagent (containing 0.03% solution of $FeCl_3.6H_2O$ and 0.3% of sulfosalicilic acid in water) was added to 3mL of the sample solution (supernatant) and the mixture was mixed on a vortex (ZX3) for 5 seconds. The absorbance was read at 500 nm using a Double beam UV-Vis spectrophotometer (T80, China). A series of standard solutions were prepared containing 0, 5, 10, 20 and 40 µg/mL of phytic acid (analytical grade sodium phytate) in 0.2N HCl. A 3mL of standard was added into 15mL of centrifuge tubes with 3mL of water which were used as a blank. A 2ml of the Wade reagent was added to each test tube and the solution mixed on a vortex mixer for 5 seconds. The mixtures were centrifuged for 10 minutes at room temperature and the absorbance of the solutions (both the sample and standard) measured at 500nm by using deionized water as a blank. A standard curve was made from absorbance versus concentration and the slope and intercept were used for calculation. The amount of phytic acid was calculated by using phytic acid standard curve

$$\text{Phytate acid}\frac{\text{mg}}{100\text{g}} = \frac{Absorbance - Intercept}{\text{Slope} * \text{Density} * \text{Weight of sample}} \qquad \text{Equation (8)}$$

3.8.2. Condensed tannin determination

The procedure by Maxson and Rooney, (1972) was used for condensed tannin estimation. About 1 g of weighed sample was extracted with 10 mL of 0.1N HCl in methanol for 24 hrs. At room temperature with mechanical shaking (Edmund Buhler, USA) then centrifuged at 3000 rpm for 5 min. One mL of the supernatant was mixed with 5 mL of vanillin HCl reagent which was prepared by combining equal volume of 8% concentrated HCl in methanol and 4% vanillin in methanol while waiting for 20 min until the reaction is completed. Finally, the absorbance was read at 500 nm after 20 min using Double beam UV-Vis Spectrophotometer

(T80, China). A stock D-catechin solution was used as the standard (20 mg D- catechin dissolved in 100 mL 1% HCl in methanol) and value of tannin was expressed in mg of D-catechin in gram of sample. Calibration curve was constructed by using a series of 0, 0.2, 0.4, 0.6, 0.8, and 1 mL of stock solution were taken in test tubes and the volume of each test tube was adjusted to 1 mL with 1% HCl in methanol. 5 mL of Vanillin-HCl reagent was added into each test tube. A standard curve was made from absorbance versus concentration and the slope and intercept were used for calculation

$$Tanninin\frac{mg}{g} = \frac{Absorbance - Intercept}{Slopex\ Density\ x\ weight\ of sample} \quad \text{Equation (9)}$$

3.9. Mineral Analyses

Calcium, Iron and Zinc were determined by Flame Atomic Absorption Spectrophotometer (AAS) (AA 6800, Japan) method as per the (AOAC, 2005) method, 985.35. One gram of composite flour and individual ingredient samples were ashed and weighed Flask used for filter the digested ash was washed with 10% HNO3 (nitric acid) and ashes were obtained from dry ashing were wetted completely with 5ml of 6N HCl and dried on hot plate at low temperature. A 7mL of 3N HCl was added to the dried ash and heated on the hot plate until the solution just boils. The ash solution was cooled to room temperature at open air in a hood and filtered through a filter paper (Whatman 42, 125 mm) into a 50 mL graduated flask and 5mL of 3N HCl was added into each crucible dishes and re-heated until the solution just boiled, then cooled and filtered into the flask. The crucible dishes were again washed three times with de-ionized water; the washings were filtered into the flask. A 2.5ml of 10% Lanthanum chloride solution was added into each graduated flask to suppress interferences during Calcium reading. Then the solution was cooled and diluted to the mark (50mL) with de-ionized water. A blank was prepared by taking the same procedure as the sample. Then the solution was used to determine Ca, Fe, Zn. Standard stock solution of Calcium, Iron and Zinc, was made by appropriate dilution. The sample and standard were atomized by using reducing air-acetylene for Ca and oxidizing air-acetylene for Zinc and Iron as a source of energy for atomization.

For Iron content determination absorbance was measured at 248.4 nm and Iron was estimated from a standard calibration curve prepared from analytical grade Iron with a range of 0, 2, 4, 6, 8 and 10mL. For Zinc concentration determination, absorbance was measured at 213.9 nm and Zinc level was estimated from a standard calibration curve prepared from analytical grade Zinc with a range of 0, 0.5, 1, 1.5, 2 and 2.5mL. For calcium content determination, absorbance was measured at 422.7 nm. Calcium content was then estimated from standard solution 0, 2, 4, 6, 8 and 10 mL prepared from $CaCo_3$. Mineral content were calculated using the following formula

$$\text{Mineral content}\left(\frac{\text{mg}}{100\text{g}}\right)=\frac{[(\text{A}-\text{B})*\text{V}]}{10\text{W}} \quad \text{Equation (10)}$$

Where: W= Weight (g) of samples;
V= Volume (V) of extract
A= Concentration (µg/ml) of sample solution;
B = Concentration (µg/ml) of blank solution

3.10. Determination of molar ratio of phytate/ mineral:

The molar ratio of phytate and minerals was determined by dividing the weight of phytate and minerals with its atomic weight of (phytate: 660g/mol; Fe: 56g/mol; Zn: 65g/ mol; Ca: 40 g/mol). Molar ratio values determine bioavailability of minerals. Critical values for bioavailability are, Phytate: Calcium <0.17; Phytate: Iron < 1 and Phytate: Zinc <5 (Norhaizan and Faizadatul, 2009; Woldegiorgis *et al.*, 2015). Molar ratios and mineral bioavailability of quality protein maize based porridge were also calculated and compared to the critical values to predict the implications for mineral bioavailability. The molar ratio between anti-nutrient and mineral was obtained after dividing the mole of anti-nutrient with the mole of minerals (Woldegiorgis *et al*., 2015).

3.11. Sensory Evaluation

Porridge samples were evaluated for color, aroma, taste, mouth-feel and overall acceptability according to the method indicated in (Muhimbula *et al.*, 2011). The porridge samples were coded with three digit numbers, randomized and presented to the judges on white plates in a fluorescent-lighted laboratory of Department of Postharvest Management. A total of 50 untrained panelists (mothers) working in Jimma University involved as a panelist score evaluated the samples on a 5-point hedonic scale, where, 1= dislike extremely, 2 = dislike moderately, 3 = neither like nor dislike, 4 = like moderately and 5 = like extremely. Mothers were used instead of the target recipient (children) because of their ability to evaluate subjectively the sensory characteristics of the formulations to the interest of their children. The panelists were instructed to rinse their mouths with water in between samples and used specification for spitting. Finally, the score of all judges for each sample were summed up and divided by the number of panelists to find the mean value.

3.12. Data analysis:

The experimental data were analyzed using MINITAB version 16 and Design-Expert®. Version 8.0, Stat-Ease software. The statistical significance of the terms in the regression equations was examined by normality test and analysis of variance (ANOVA) for each response and the significance test was set at 5% level. Scatter plot (to check the data normal distributed) of for each response variables, overlaid contour plot (to optimize the range of best nutrient optimization for selected nutrients and by using responses) and optimization for best nutrient proportion ratio for nutritional quality and sensory acceptability of porridge for target group. Analytical tools like normal probability plot of residuals indicate that the error terms of all the parameters were normally distributed.

4. RESULTS AND DISCUSSION

This study was conducted to determine the best mixture of four ingredients (flours of QPM, *Anchote*, Carrot and Soybean) to develop porridge for under 5 age of children. Flour samples were used to determine the functional properties of while, porridge was used to determine nutrient and anti-nutrient contents as well as sensory quality of the porridge. The results of the statistical analyses are presented and discussed in Tables and Figures as indicated in the following sections.

4.1. Functional Properties

The functional properties of flours determine the application and use of the flours for various food products development. The mean values of bulk density (BD), water absorption capacity (WAC), oil absorption capacity (OAC) and viscosity (V) are summarized in Table 6. Diagnostic tools like normal plot of residuals indicate that the residuals of all the parameters were normally distributed. Appendix Table 1 shows the P-values obtained from ANOVA results for the mixture experimental design models.

Table 6: Mean values for functional properties of ingredient and composite flour samples

	Components				Functional Properties			
Run	A	B	C	D	BD(g/mL)	WAC(mL)	OAC(mL)	VISCOSITY(Pa.s)
CF1	0.85	0.1	0.05	0	0.72	1.69	1.54	401
CF2	0.45	0.2	0.15	0.2	0.77	1.69	1.14	200
CF3	0.65	0.1	0.05	0.2	0.80	1.68	1.15	248
CF4	0.55	0.2	0.05	0.2	0.84	1.69	1.18	273
CF5	0.75	0.2	0.05	0	0.89	1.56	1.88	430
CF6	0.55	0.1	0.15	0.2	0.70	1.67	1.16	220
CF7	0.75	0.1	0.15	0	0.72	1.34	1.81	428
CF8	0.65	0.2	0.15	0	0.88	1.35	1.89	420
CF9	0.65	0.15	0.1	0.1	0.79	1.41	1.55	300
CF10	0.75	0.125	0.075	0.05	0.72	1.39	1.55	402
CF11	0.55	0.175	0.125	0.15	0.82	1.55	1.29	268
CF12	0.65	0.125	0.075	0.15	0.81	1.54	1.33	280
CF13	0.6	0.175	0.075	0.15	0.83	1.53	1.39	336
CF14	0.7	0.175	0.075	0.05	0.75	1.32	1.64	378
CF15	0.6	0.125	0.125	0.15	0.76	1.56	1.36	330
CF16	0.70	0.125	0.125	0.05	0.72	1.38	1.69	376
CF17	0.65	0.175	0.125	0.05	0.78	1.37	1.64	401
A	1.00	-	-	-	0.96	4.5	1.85	10230
B	-	1.00	-	-	0.94	2.5	2.25	927
C	-	-	1.00	-	0.71	2.3	2.2	860
D	-	-	-	1.00	0.79	3.75	1.1	1162

A= QPM, B= *Anchote*, C=Carrot, D = Soybean, CF= Complementary Food= BD= Bulk Density WAC= Water Absorption Capacity = OAC= Oil Absorption Capacity

4.1.1. Bulk density

The mean bulk density values for the ingredient flours were QPM 0.96, *Anchote* 0.94, carrot 0.71, and soybean 0.79 g/mL. But BD of the composite flours varied from 0.70 to 0.89 g/mL. Significant interaction ($P<0.05$) effects were observed between QPM with *Anchote* and *Anchote* with carrot flour of the mix (Appendix Table 1). The model adequacy in predicting the experimental results (bulk density) of the formulation was checked by normality test ($P> 0.05$).

A normality test is a statistical process used to determine if a sample or any group of data fits a standard normal distribution. A normality test can be performed mathematically or graphically. (R^2 value= 78.9%) and found to be satisfactory. The regression model for bulk density was represented in (Equation. 11) as indicated in quadratic model with four variables

$$\text{Bulk density } = 0.213\text{A} - 7.74\text{B} - 9.94\text{C} + 7.95\text{D} + 13.36\text{AB} + 12.42\text{AC} - 8.12\text{AD} + 27.54\text{BC} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{Equation } (11)$$

Where: A = QPM, B = Anchote, C = Carrot and D = Soybean

The highest bulk density (0.89 g/mL) was obtained from blend with 75% QPM, 20% *anchote*, 5% Carrot and 0% soybean (Table 6). The low of BD (0.70g/mL) was from high proportion ratio of carrot and soybean flour (QPM 55%, *anchote* 10%, carrot 15% and soybean 20%). The low bulk density would allow children to swallow foods with ease without choking or suffocation and results in high energy and nutrient density (Inyang and Zakari, 2008; Michaelson *et al.*, 2009).The ingredients and composite flours that had low bulk density have nutritional significance because more of the products can be eaten by infants and children. Bulk density indicates the characteristics of container or package, product density influences the amount and strength of packaging material and texture or mouth feel (Wilhelm *et al.,* 2004).

The contour plot shown in Figure 3a indicates that bulk density increased with increasing ratio of QPM and *anchote* flours. The original BD values of these two flours had an effect on the composite flours too. This may relate to high fiber contents in QPM and *Anchote* flours which contribute to increasing bulk density of the flour. This finding is in agreement with research work done by different researchers; those found that BD of complementary food prepared from soybean and maize flour increased from 0.61 to 0.73g/ mL primarily due to the maize ingredient (Mishra, *et al.*, 2012). In contrast, to this increased proportion of carrot and soybean flour decreased bulk density of composite flour as indicated in contour plot (Figure 3a). But other researchers reported that germinated maize flours reduced the bulk density of flour (Gernah, 2011). The reduction in the bulk density due to malting was a reflection of the activity of alpha - amylase enzyme, which was activated during malting process and dextrinifies (amylase is activated which dextrinified starch to simple sugars which does not swell when cooked. During malting the activated amylase enzyme dextrinified starch) its constituent sub-units (Ijarotimi and Keshinro, 2012).

4.1.2. Water absorption capacity

The mean water absorption capacity of composite flour ranged from 1.32 to 1.69 mL as shown in Table 6. The WAC values of individual flours of QPM, *Anchote*, carrot and soybean were 4.5, 2.5, 2.3, and 3.75 mL respectively. The model acceptability in predicting the experimental results (WAC) of the formulation was checked by normality test ($P > 0.05$) (R^2 value= 90.6 %) and found to be satisfactory. The regression model for water absorption capacity was represented in (Equation. 12) as indicated in quadratic model with four variables

$$\text{Water absorption capacity} = 1.38\text{A} - 15.5\text{B} - 12.6\text{C} + 21.5\text{D} + 22.1\text{AB} + 13.1\text{AC} - 26\text{AD} + 42.9\text{BC} \ldots\ldots \text{Equation (12)}$$

Where: A = QPM, B = Anchote, C = Carrot and D = Soybean

The higher water absorption is an indication of the amount of water available for gelatinization (Victor *et al*., 2013). Low water absorption capacity is important for increasing energy density of complementary foods. Highly significant interaction ($P<0.01$) effects in linear and quadratic models were observed between QPM with soybean flour and significant difference ($P<0.05$) between QPM with *Anchote* flour of the mix in Appendix Table 1.

Figure 3b, indicates that, in the mix, as the percentage of soybean flour increases to 20%, WAC also increased from 1.32 to 1.69mL. This might be due to the higher protein content that allows the mix to hold more water in the matrix. Comparable result also indicated on QPM with soybean blend cookies where water absorption capacity increased from 1.26 to 1.46 with increase in the level of soybean flour (Mishra *et al*., 2012). However, Beruk *et al*. (2015) reported that water absorption capacity increased in complementary foods when the level of QPM flour increased. Chemical composition that enhances the WAC of flours is carbohydrates because this component contains hydrophilic parts, such as polar or charged side chains (Lawal and Adebowale, 2004). This observed reduction in this study might be due to the fact that amylase activities were developed during the process of germination of QPM that results in reduced levels of carbohydrate, since those enzymes might degrade major portion of starch during the germination process. According to Sodipo and Fashakin (2011), amylase enzymes in grains; saccharify/dextrinify the starch in the grain to dextrin and maltose, which absorbs little water when cooked.

4.1.3. Oil absorption capacity

The mean oil absorption capacity of composite flour values ranged from 1.14 to 1.89 mL as shown in Table 6. OAC from the different ingredients were not significant (P>0.05). The model suitability in expecting the experimental results (OAC) of the formulation was found to be satisfactory (P> 0.05) (R^2 value= 98.1%). The regression model for oil absorption capacity was represented in (Eq. 13) as indicated in quadratic model with four variables

$$\text{Oil absorption capacity } = 0.7\text{A} - 3.9\text{B} - 3.5\text{C} + 1.6\text{D} + 11.9\text{AB} + 10.5\text{AC} - 1.9\text{AD} + 4.6\text{BC} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{Equation (13)}$$

Where: A = QPM, B = Anchote, C = Carrot and D = Soybean

Oil absorption capacity of QPM, *Anchote*, carrot, and soybean flours were 1.85, 2.25, 2.2 and 1.1 mL respectively. The highest OAC was found in the sample having proportion ratio of QPM 65%, a*nchote* 20%, carrot 15% and soybean 0%. The contour plot shown in Figure 3c indicated that the OAC of complementary flours increased when the levels of QPM, *anchote* and carrot flour increased. This might be observed due to the low fat content of QPM, *Anchote* and carrot flours. On the other hand, when the level of soybean flour increased from 0 to 20% then the amount of oil absorption capacity decreased from 1.89 to 1.14mL. This lower value of oil absorption capacity is associated with the high amount of fat content of soybean flour. Therefore, absorption of oil by food products improves mouth feel and flavor retention for children. High oil absorption capacity is important for increasing energy density of complementary foods for children (Abioye, 2011; Beruk *et al.*, 2015). The minimum value of OAC was found when the proportion ratio was QPM 45%, *Anchote* 20%, carrot 15% and soybean 20%. This finding is also in agreement with the researchers who studied cookies prepared from soybean and wheat, as the ratio of Soybean flour increased, OAC decreased due to the high fat content in soybean (Mishra *et al.*, 2012).

4.1.4. Viscosity

The mean viscosity of porridges ranged from 200 to 430 Pa.s (Table 6). The model capability in predicting the experimental results (viscosity) of the formulation was checked by normality test (P> 0.05) (R^2 value= 93.4%) and found to be satisfactory. The regression model for viscosity was represented in (Equation. 14) as indicated in quadratic model with four variables:-

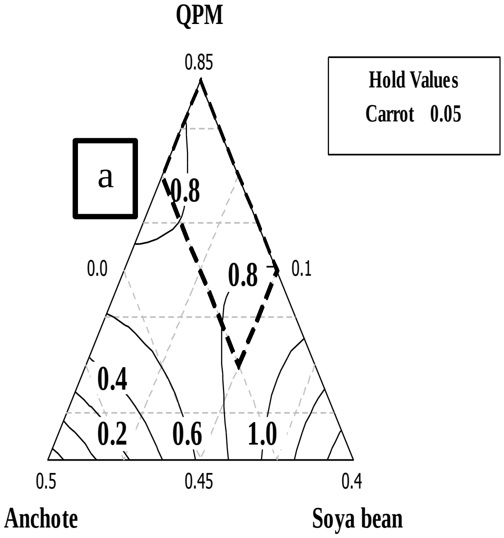
$$\text{Viscosity } = 312\text{A} - 1307\text{B} - 348\text{C} - 1055\text{D} - 607\text{AB} + 1840\text{AC} + 1025\text{AD} - 3438\text{BC} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{Equation } (14)$$

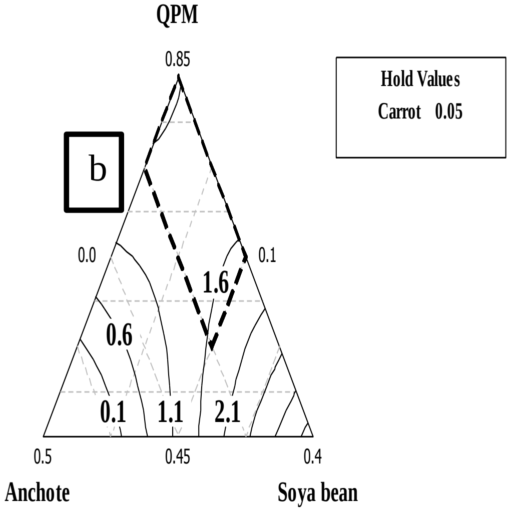
Where: A = QPM, B = Anchote, C = Carrot and D = Soybean

The viscosity values for the ingredient flours were QPM: 10230 Pa.s, *Anchote*: 927 Pa.s, carrot: 860 Pa.s, and soybean: 1162Pa.s. Although there was no significant difference among the ingredients, the trend showing that high viscosity was obtained from high proportion of QPM and *Anchote* flours compared to those obtained from soybean and carrot flours. The highest viscosities were obtained from 75% QPM, 20% *Anchote*, 5% carrot, and 0% soybean (Table 6). When, complementary food for children is considered, the lower the viscosity the better to feed children.

Figure 3d shows that viscosity of composite flours increases with increasing proportion ratio of QPM and *Anchote* flours. This is due to the high starch content found in QPM and *Anchote* flours. The lowest viscosity was found when the proportion ratio for QPM, *Anchote*, carrot and soybean was 45%, 20%, 15% and 20% respectively. Due to the low starch content of carrot and soybean flour, the addition of these flours led to reduction in viscosity this might be significantly affected by gelatinization characteristics of the starch during cooking. However, this influence can be minimized through reducing the starch level using germinated QPM seeds flour.

Hussain and Uddin, (2011) soaking and germination of cereals could reduce viscosities of porridge. The reduction in viscosity of the malted diet is a result of the activity of amylase developed during malting process, which degrades the starch to simpler units (Fagbemi, 2007). The result measures are in agreement with that of Ikujenlola (2014) and Adetuyi *et al*. (2009) where malting or sprouting has viscosity reducing effect on cereals and legumes. Similar result reported (Kodandaram and Bhotmange, 2014). During manufacturing of food aimed at supplying a substantial amount of nutrients of complementary foods, it is desirable to include materials that do not form highly viscous porridge at low solids concentrations for children the age of five years.





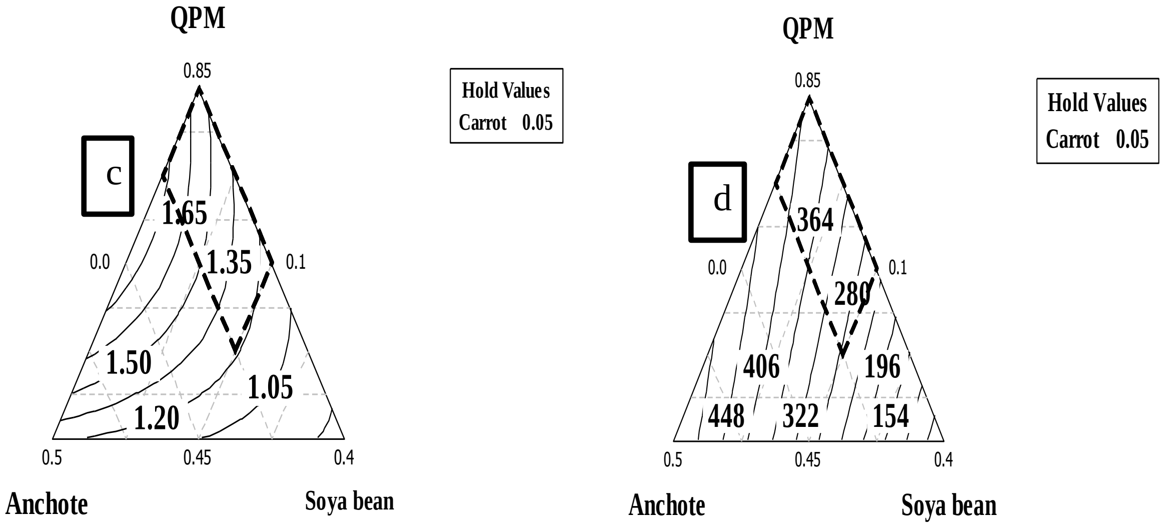


Figure 3: Contour plots of (a) Bulk density and (b) water absorption capacity (c) Oil absorption Capacity and (d) Viscosity holding carrot constant at 5%

4.2.Quality Protein Maize Based Complementary Food (Porridge) Prepared From Composite Flours

The development of QPM based complementary food for under the 5 years children were selected considering the existing feeding habit of children in Ethiopia. Data on proximate composition (moisture, ash, crude protein, crude fat, crude fiber and carbohydrate), micronutrients (Calcium, Iron, Zinc) β-carotene content, anti-nutritional factors (phytate, tannin), and sensory properties of complementary food made from the mixtures are indicated below.

4.3. Proximate Composition

The proximate compositions of the raw ingredients (QPM, *anchote,* carrot and soybean) and formulated porridges were shown in Table 7. Analytical tools like normal probability plot of the residuals confirmed that the error terms of all response variables are normality distributed. The P-value for ANOVA was summarized in Appendix Table 2. Mixture compositions of proximate analysis and fitted regression coefficients of individual and formulated products are summarized in Appendix Table 6.

Table 7: Mean values for proximate composition of porridge and individual flours

	Components				**Proximate components**							
Run	A	B	C	D	P.M.C%	F.M.C%	Ash%	Crude Protein%	Crude fat%	Crude fiber%	CHO%	Energy kcal
CF1	0.85	0.1	0.05	0	54	6.5	2.01	11.01	5.5	6	69.0	369.5
CF2	0.45	0.2	0.15	0.2	59.1	6.6	3.5	18.5	9.25	3.5	58.7	391.9
CF3	0.65	0.1	0.05	0.2	58.3	5.8	3.65	18.5	9.27	4.68	58.1	389.8
CF4	0.55	0.2	0.05	0.2	57.5	5.6	3.87	18.4	9.23	3.84	59.1	392.9
CF5	0.75	0.2	0.05	0	47.8	6.2	3.25	10.25	5.12	5	70.2	367.8
CF6	0.55	0.1	0.15	0.2	43.8	5	3.6	19.0	9.5	3.6	59.3	398.7
CF7	0.75	0.1	0.15	0	52.4	6.6	2.22	10.7	5.39	6	69.1	367.7
CF8	0.65	0.2	0.15	0	60	6.62	2.82	10.5	5.28	4.82	70.0	369.4
CF9	0.65	0.15	0.1	0.1	54.1	5.61	2.12	14.4	7.23	4.25	66.4	388.2
CF10	0.75	0.125	0.075	0.05	52.7	6.05	1.85	11.6	5.92	4.89	69.7	378.4
CF11	0.55	0.175	0.125	0.15	54.7	5.68	3.25	16.1	8.095	3.78	63.1	389.6
CF12	0.65	0.125	0.075	0.15	50.4	5.7	2.2	16.3	8.17	4.54	63.1	391.1
CF13	0.6	0.175	0.075	0.15	51.3	5.81	3.65	16.0	8.01	4.76	61.8	383.2
CF14	0.7	0.175	0.075	0.05	50.4	5.56	1.75	12.14	6.07	5.5	69.0	379.1
CF15	0.6	0.125	0.125	0.15	45.8	5.25	2.95	16.06	8.03	4.32	63.4	390.1
CF16	0.70	0.125	0.125	0.05	51.4	5.8	2.97	12.31	6.155	4.21	68.6	378.9
CF17	0.65	0.175	0.125	0.05	49.2	5.63	2.25	12.61	6.305	4.33	68.9	382.7
A	1.00	-	-	-	61	8.5	2	10.06	1.5	4.86	77.83	360.56
B	-	1.00	-	-	52	7.25	4	3.64	1.36	4.7	78.05	339.00
C	-	-	1.00	-	45	6.25	1.25	3.2	0.66	3.26	81.78	335.86
D	-	-	-	1.00	42	6.00	3	46.54	23.7	3.13	17.37	468.98

A= Quality protein maize; B= *Anchote*; C=Carrot; D = Soybean; P.MC= porridge moisture content; F.M.C= flour moisture content; CF= Complementary food

4.3.1. Moisture content (MC)

Mean moisture content of the ingredients pure flours was: QPM: 8.5%, *Anchote:* 7.25%, carrot: 6.25% and soybean: 6%. But the moisture content of porridge made from composite flours ranged from 43.8 to 60%; while the value of flour moisture content ranger from 5-6.62% in the seventeen composite porridge mixtures. The interaction of QPM with carrot, QPM with soybean and *Anchote* with carrot flour was significant ($P<0.05$) on the moisture content of porridge samples on quadratic model. The lower the moisture contents the better for children because of its higher energy density (Akinola *et al.*, 2014). The model acceptability in predicting the experimental results (moisture content) of the formulation was checked by normality test ($P> 0.05$) (R^2 value= 83.4%) and found to be satisfactory. The regression model for moisture content was represented in (Equation.15) as indicated in quadratic model with four variables

$$\text{Moisture content} = 6.55\text{A} - 39.37\text{B} - 90.37\text{C} + 71.93\text{D} + 46.65\text{AB} + 103.12\text{AC} - 93.24\text{AD} + 257.07\text{BC} \ldots\ldots \text{Equation (15)}$$

Where: A = QPM, B = Anchote, C = Carrot and D = Soybean

The contour plot shown in Figure 4a indicates that the moisture content of the porridge was altered by the different blending ratios of the four ingredients. As the levels of QPM and *anchote* flours increased, the moisture content of the porridge also increased. This might be due to high starch content of QPM and *anchote* flour which increased the moisture content of the porridge. The lowest moisture content 5% was affecting from mixture ratio of 55% QPM, 10% a*nchote,* 15% carrot, and soybean 20% and the highest (6.62%) is from 65% QPM, 20% *anchote*, 15% carrot and soybean 0% (Table 7).

This result is in agreement with that of Amankwah *et al*. (2009) who reported that moisture content after formulating weaning food from maize, rice, soybean and fishmeal was 5.47 to 6.87%, but when the levels of maize flours were increased in the complementary foods, the amount of moisture content also increased. Similarly, higher moisture contents were reported in *Anchote* (Habtamu, 2014). According to Alozie *et al*. (2009), the flours with lower content of moisture (<10%) are suitable for inactivation of microbes. In the current finding, low proportion of QPM and *Anchote* flour and high proportion of carrot and soybean flour is preferred because at this proportion the complementary food had low moisture content which is within the range of the moisture content of complementary foods recommended being 5% (CODEX, 1991).

4.3.2. Total ash

The total ash content of complementary foods samples ranged from 1.75 to 3.87% us compared to the total ash content flours of QPM, *anchote*, carrot, and soybean were 2%, 4%, 1.25%, and 3%, respectively in Table 7. The ash content of complementary food samples significant ($P<0.05$) showed the interaction of QPM with soybean and anchote flour. The model acceptability in predicting the experimental results (ash content) of the formulation was checked by normality test ($P> 0.05$) (R^2 value= 72.34%) and found to be satisfactory. The regression model for Ash content was represented in (Equation. 16) as indicated in quadratic model with four variables

$$\text{Total ash } = -5\text{A} - 126.5\text{B} - 137.6\text{C} + 140.6\text{D} + 193.5\text{AB} + 180.7\text{AC} - 168.2\text{AD} + 308.2\text{BC} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{Equation (16)}$$

Where: A = QPM, B = Anchote, C = Carrot and D = Soybean

The total ash content was positively influenced by *Anchote* and soybean blending ratio (Figure 4b). The highest ash content was obtained from the blend with 55% QPM, 20% Anchote, 5% carrot and 20% soybean flour. This might be attributed to the, high mineral content of in *anchote* and soybean flour compared to QPM and carrot flours. High ash content found in in *anchote* flours Habtamu (2014). Tirhas *et al.*, (2015) porridge prepared from sweet potato, soybean and moringa flour high ash content in soybean flour.

The lowest total ash value corresponded to the sample containing low proportion of *Anchote* and soybean flour (QPM, *anchote*, carrot and soybean were 0.70, 0.175, 0.075 and 0.05 respectively). Akinola *et al.* (2014) complementary food prepared from maize, soybean, peanut and carrot, the ash content increased from 5.12% - 7.52% due to, high mineral content of soybean flour. Total ash content represents the total mineral contents in a food sample

(Neha and Ramesh, 2012). According to WHO (1996), total ash content of 1-3% is recommended in the diets of children under the age of five. The present findings can be used to fulfill the ash requirements (1 to 3%) of children under five years old.

4.3.3. Crude protein

The mean protein content of complementary food samples prepared from seventeen formulations is summarized in Table 7. The protein content of the ingredients was: 10.06, 3.64, 3.2, and 46.54 % for QPM, *Anchote*, carrot and soybean respectively in Table 7. The interaction effect of QPM and soybean flour was significant ($P<0.05$) on the protein content of porridge samples on linear model. The regression model for crude protein content was represented in (Equation.17) as indicated in quadratic model with four variables

$$\text{Crude ptotein } = 8.2A - 66.2B - 72.4C + 130.6D + 101AB + 101.6AC - 104AD + 211BC \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{Equation (17)}$$

Where: A = QPM, B = Anchote, C = Carrot and D = Soybean

The protein content of the porridge samples ranged from 10.25 to 19.01% (Table 7). The highest protein content (19.01%) was recorded in the porridge sample containing the blending ratio of 55% QPM, 10% *Anchote*, 15% carrot, and 20% soybean flour (Table 7). It was observed from the contour plot that the mean protein content of porridge samples increased with increasing supplementation level soybean flour in the blends (Figure 4c). This is because of the high protein content of soybean seeds with highly digestible amino-acids (Carrera *et al.*, 2011). Therefore, as this study aims to solve malnutrition problems through food based approach among children under the age of five years, it is important to promote the wide consumption of porridge prepared from the formulation in which the protein content was registered to be the highest in order to tackle the prevalence of protein energy malnutrition among children. The lowest protein content (10.25%), however, was recorded in porridge sample prepared from the formulation with the lowest proportion (0%) of soybean flour (Table 7).

In agreement with the present result, Onoja (2014) reported the highest crude protein (37 to 54%) content of soybean flour in the formulation of porridges. Akinola, *et al*. (2014) also reported the protein content of 16.64 to 21.46% in the complementary food prepared from yellow maize, millet, guinea corn, soybean, carrot, and groundnut. For children under the age of five, >18% protein content in a complementary food is considered adequate as Recommended Daily Allowance (RDA) (WHO/ FAO, 2004).

4.3.4. Crude fat

The crude fat content of the complementary foods were significantly ($P<0.05$) affected by the different blending ratios of the four ingredients. The fat content of the ingredients were 1.5, 1.36, 0.66 and 23.7% for QPM, *Anchote*, carrot and soybean respectively. The interaction effect of QPM with soybean, flour was significant ($P<0.05$) on the fat content of porridge samples on linear model. The effects of blending ratio of each ingredient (QPM, *Anchote*, carrot, and soybean) were analyzed using ANOVA and p-values for both linear and quadratic model (Appendix Table 2). The model adequacy in predicting the experimental results (mean fat contents) of the formulation was checked by normality test ($P> 0.05$) (R^2 value= 99.54%) and found to be acceptable. The regression model for crude fat content was represented in (Equation. 18) as indicated in quadratic model with four variables

$$\text{Crude fat} = 4.28A - 30.4B - 33.2C + 62.61D + 46.54AB + 46.84AC - 48.7AD + 98.85BC \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{Equation (18)}$$

Where: A = QPM, B = Anchote, C = Carrot and D = Soybean

The fat content of the porridge samples ranged from 5.5 to 9.5% (Table 7). The highest fat content (9.5%) was recorded in the porridge sample containing the blending ratio of 55% QPM, 10% *Anchote*, 15% carrot, and 20% soybean (Table 7). Figure 4d contour plot shows the mean fat content of porridge samples increased with increasing supplementation in the amount of soybean flour in the blend proportion. This is because of the high fat content of soybean seed (Kim, 2009; Carrera *et al.,* 2011). Fat is important in the diets of infants and young children because it provides essential fatty acids, facilitates absorption of fat soluble vitamins, and enhances dietary energy density and sensory qualities (Dew and Brown, 2002).

The lowest fat content (5.5 %), however, was determined in porridge sample prepared from the formulation with the lowest proportion (0 %) of soybean flour (85 % QPM, 10 % *Anchote*, 5 % carrot) (Table 7). Similar observation reported by Aleem *et al.* (2012) when an increase in fat content of complementary food with an increase in proportion of soybean flour. The recommended daily allowance in the meals for under age of five children is between 9 to 25% (FAO, 2004).

4.3.5. Crude fiber

The crude fiber content of flour QPM, *Anchote*, carrot and soybean were 4.86%, 4.7%, 3.26% and 3.13 respectively. The model acceptability in predicting the experimental results (fiber contents) of the formulation was checked by normality test (P> 0.05) (R^2 value= 88.2%) and found to be acceptable. The regression model for crude fiber content was represented in (Equation. 19) as indicated in quadratic model with four variables

$$\text{Crude fiber} = 0.213\text{A} - 7.74\text{B} - 9.94\text{C} + 7.95\text{D} + 13.36\text{AB} + 12.42\text{AC} - 8.12\text{AD} + 27.54\text{BC} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{Equation (19)}$$

Where: A = QPM, B = Anchote, C = Carrot and D = Soybean

The crude fiber content was directly associated with QPM supplement levels with the highest 6% of fiber content found in the blend of QPM, *Anchote,* carrot and soybean with 85, 10, 5, and 0% respectively. High fiber content might be important in terms of healthy life for adults to prevent or control diseases like diabetics and heart diseases (Anderson *et al.,* 2009). Most children don’t get enough fiber in their daily diet and this leads to constipation (Kranz *et al.,* 2012). Therefore, the better the fiber content, the higher the benefit to smoothen the digestion process and bowl movement of children. However, complementary foods with low fiber content (<5 %) is very important since it helps in the safety of children considering their stomach capacity since they have to consume more to get satisfied to meet their daily energy requirement (Slavin, 2008). Moreover, low crude fiber is nutritionally appreciated because it traps less proteins and carbohydrates (Reicks *et al.,* 2014).

Figure 4e indicates that, the fiber content does not change ($P>0.05$) substantially with the proportions of the ingredients. Increase in crude fiber content was observed with an increase in proportion of QPM and *Anchote* flour. This may be due to the high starch content of QPM and *Anchote* as compared to other flours. Similar results was also reported by Meseret (2011) where weaning food prepared from QPM with soybean blends have high starch content, Habtamu (2014) also high fiber content in Anchote tuber crops. The lowest (3.5%) crude fiber content was found from high proportion ratio of carrot and soybean flour, the blend of QPM, *Anchote*, carrot and soybean: 45, 20, 15 and 20% respectively (Table 7).

4.3.6. Carbohydrate

The utilizable carbohydrates of the ingredient were QPM 77.83%, *Anchote* 78.05%, carrot 81.78%, and soybean 17.37% flour. QPM and *Anchote* almost have equal capacity to deliver the required carbohydrate level. Carbohydrate content was significantly ($P<0.01$) different by the ingredients in both linear and quadratic models (Appendix Table 2). This is because, except soybean flour, the three ingredients: QPM, *Anchote* and carrot had high carbohydrate content. The model adequacy in predicting the experimental results (carbohydrate contents) of the formulation was checked by normality test ($P> 0.05$) (R^2 value= 98.8%) and found to be acceptable. The regression model for carbohydrate content was represented in (Equation. 20) as indicated in quadratic model with four variables

$$\text{Carbohydrate content} = 79A + 381.8B + 485C - 340D - 411AB - 497AC + 459AD - 976BC \ldots\ldots \text{Equation (20)}$$

Where: A = QPM, B = Anchote, C = Carrot and D = Soybean

The carbohydrate contents of complementary flours in this study were in the range of 58.01 to 70.2 %. It is lower than studies conducted in Ethiopia quality protein maize based porridge prepared with chickpea OFSP and Teff the amount of carbohydrate content of porridge were 71.91 to 75.37% (Beruk *et al.,* 2015). This lower carbohydrate contents might be blends of soybean it reduced the carbohydrate content of porridge; due to protein and fat content of soybean. The highest carbohydrate value (70.2%) of porridge made from 75% QPM, 20% *Anchote*, 5% carrot and 0% soybean.

As shown in Figure 4f, the amount of carbohydrate increases with an increase in proportion of QPM and *Anchote* flour. Result of this study is also in agreement with study of Ikujenlola and Adurotoye, (2014) who reported that complementary food prepared from QPM and Steamed Cowpea increased the carbohydrate content from 69 to 74% when the amount of QPM flour was increased. Similar results were also reported by (Akinola *et al*., 2014). The lowest carbohydrate content value (58.1%) corresponded to the sample containing high proportion of soybean (20%). A similar trend was reported in a research work of Okoye *et al.* (2008) where the carbohydrate content was reduced from 73.43 to 34.86% with the increasing the amount of soybean flour in the complementary foods. The recommended daily allowance of carbohydrate content for under age of five children were >58% (FAO/WHO, 2012) which is in line with result of this study.

4.3.7. Gross energy

Gross energy contents of the raw ingredients were 360.56 kcal/100g for QPM flour, 339 kcal/100g for *anchote* flour, 335.86 kcal/100g for carrot and 468.98 kcal/100g for soybean flour. The mean energy content of formulated complementary foods ranged from 368.38 to 398.7kcal/100g in the final porridge product (Table 7). The model adequacy in predicting the experimental results (energy content) of the formulation was checked by normality test (P> 0.05) (R^2 value= 94.1%) and found to be satisfactory. The regression model for energy content was represented in (Equation. 21) as indicated in quadratic model with four variables

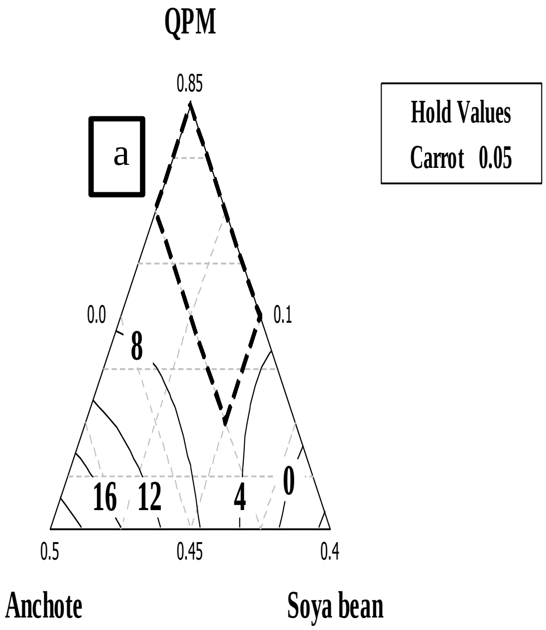
$$\text{Energy} = 391A + 1000B + 1383C - 289D - 837AB - 1200AC + 1002AD - 2221BC \ldots\ldots \text{Equation (21)}$$

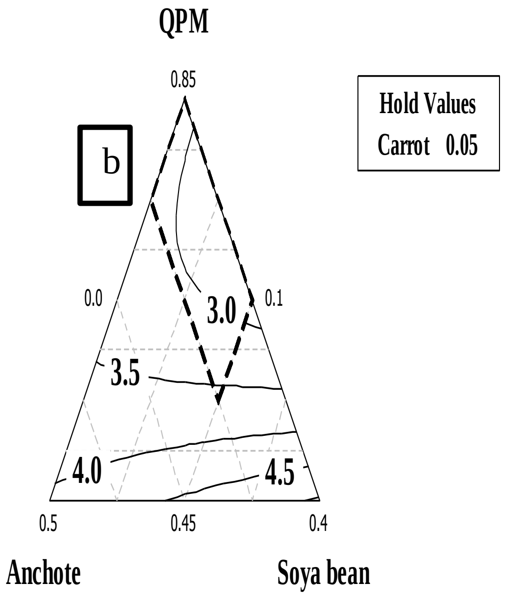
Where: A = QPM, B = Anchote, C = Carrot and D = Soybean

A significant interaction (P<0.05) between QPM and soybean was observed, with the highest energy value (398.7kcal) obtained from the sample containing high level of QPM, *Anchote*, carrot and soybean: 55, 10, 15 and 20% respectively. The contour plot shown in Figure 4g indicates in the working domain, that QPM, and *Anchote* and soybean flour supplementation significant increases the gross energy of porridge as compared to carrot flour. This observation was attributed to the high content of gross energy in, associated with more fat and protein content of the soybean flour. The calories in children’s diet are provided mainly by protein, fat and carbohydrates (Amankwah *et al.*, 2009).

Food product therefore are developed using high protein, fat and calorie contents using soybean flour (Induja *et al.,* 2012). According to Nwosu *et al*. (2014), gruels prepared from common maize, soybean and moringa have the energy value increasing from 456-469 kcal/100g, this variation might be in our study blends of carrot it reduced the energy content of porridge due to low protein and fat content of carrot flour implies low energy content of porridge. Similar result reported, low energy content had in carrot flour (Gocmen *et al.*, 2015).

In this study, the lowest energy value (367.7kcal) corresponded to the sample containing low level of soybean flour (QPM, *Anchote,* carrot and soybean: 75, 10, 15 and 0 %). This mixture also gave low level of protein and fat content in the porridge. According to Ayo *et al.* (2011) the recommended daily allowance of energy for complementary foods in developing countries ranges from 370 to 420kcal per 100gm. The energy contents of porridges made from different flour are in the range of 368.38 to 398.7kcal/100g, which can satisfy energy requirements as per the recommended values for target group per serving.


QPM
0.85
a
Hold Values
Carrot 0.05
0.0
0.1
8
16
12
4
0
0.5
0.45
0.4
Anchote
Soya bean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Carrot 0.05
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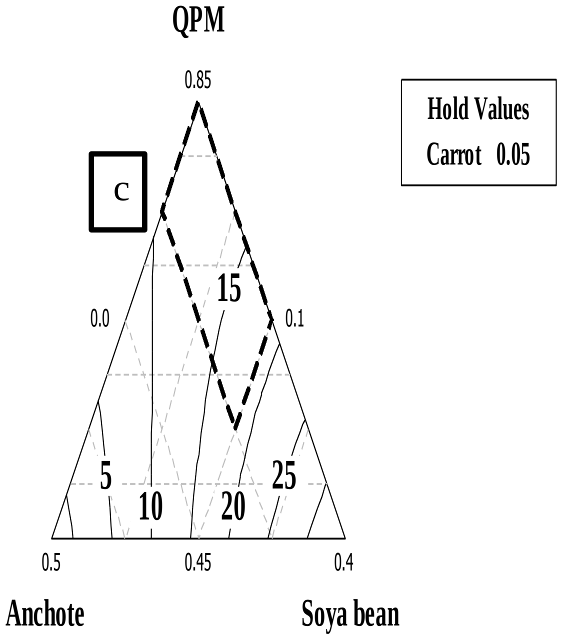
Anchote
Soya bean


QPM
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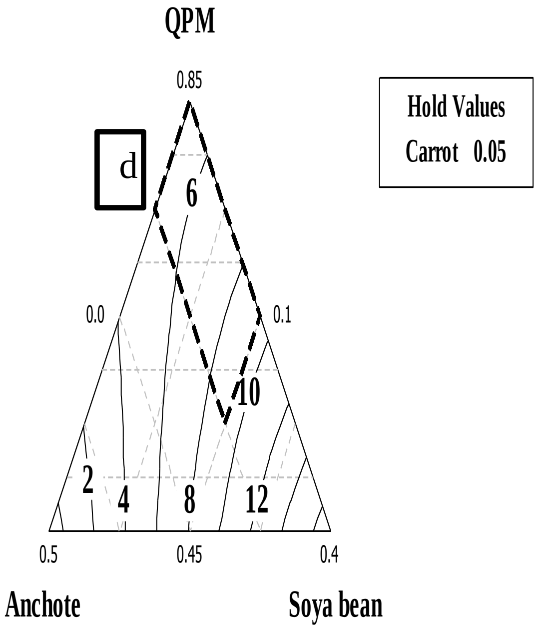
Soya bean


QPM
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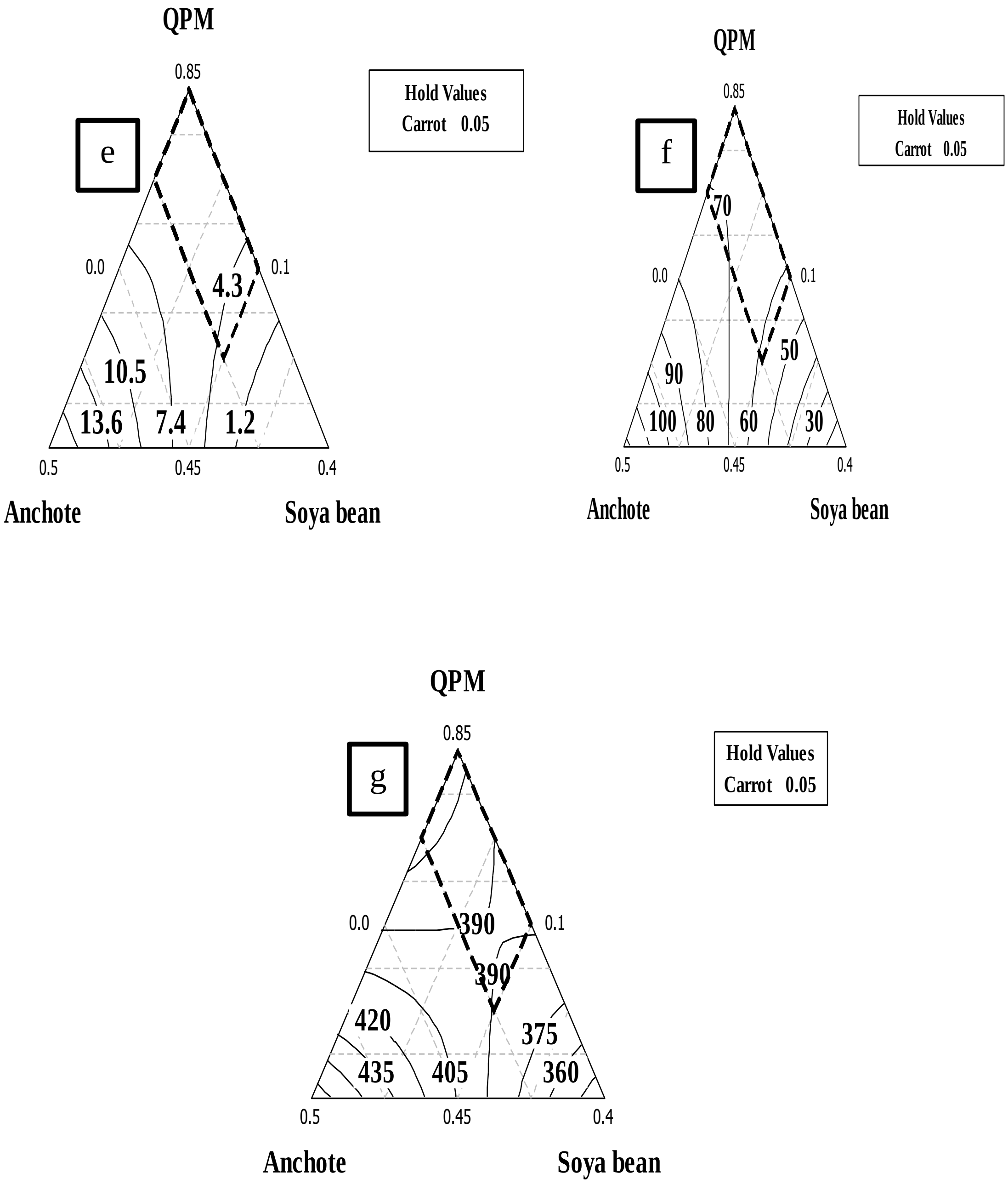

Figure 4: Contour plots of (a) moisture content (b) ash content (c) crude protein (d) crude fat (e) crude fiber (f) carbohydrate content and (g) energy value of porridge holding carrot constant at 5%

4.4.Selected minerals

The mean values of mineral contents (Calcium Iron and Zinc) and beta carotene of porridges made from all seventeen formulations and ingredients are presented in Table 8. The Analysis of variance has shown significant differences (P<0.05) in mineral content and beta carotene content of the porridge (Appendix Table 3).

Table 8: Mean values of mineral content for porridge and individual flours

Components					**Mineral compositions**		
Run	A	B	C	D	Calcium (mg/100g)	Iron (mg/100g)	Zinc (mg/100g)
CF1	0.85	0.1	0.05	0	101.7	5.00	2.27
CF2	0.45	0.2	0.15	0.2	209.8	6.59	3.25
CF3	0.65	0.1	0.05	0.2	138.6	5.50	2.72
CF4	0.55	0.2	0.05	0.2	190.6	6.99	2.70
CF5	0.75	0.2	0.05	0	192.3	5.21	2.20
CF6	0.55	0.1	0.15	0.2	204.2	5.57	2.56
CF7	0.75	0.1	0.15	0	120.9	5.19	2.32
CF8	0.65	0.2	0.15	0	195.3	5.57	2.57
CF9	0.65	0.15	0.1	0.1	141.2	5.29	2.29
CF10	0.75	0.125	0.075	0.05	125.3	5.37	2.37
CF11	0.55	0.175	0.125	0.15	185.5	5.77	2.77
CF12	0.65	0.125	0.075	0.15	144.6	5.67	2.67
CF13	0.6	0.175	0.075	0.15	154.4	5.68	2.67
CF14	0.7	0.175	0.075	0.05	143.9	5.39	2.39
CF15	0.6	0.125	0.125	0.15	135.4	5.46	2.46
CF16	0.70	0.125	0.125	0.05	150.1	5.43	2.42
CF17	0.65	0.175	0.125	0.05	142.3	5.54	2.54
A	100	-	-	-	78.19	3.61	2.27
B	-	100	-	-	109.49	6.50	2.8
C	-	-	100	-	29.42	2.05	1.4
D	-	-	-	100	251.67	7.12	4.1

A= Quality protein maize= B= *Anchote* = C=Carrot =D = Soybean = CF= complementary food

4.4.1. Calcium content

The mean Calcium contents of QPM, *Anchote*, carrot and soybean flours were analyzed and reported to be 78.19, 109.49, 29.42 and 251.67 mg/100g respectively. The interaction effect of QPM and *Anchote*; QPM and soybean flour was highly significant ($P<0.01$) on the Calcium content of porridge samples on both linear and quadratic models in Appendix Table 3. The model adequacy in predicting the experimental results (Calcium contents) of the formulation was checked by normality test ($P> 0.05$) (R^2 value= 89.5%) and found to be acceptable. The fitted quadratic regression model for Calcium content is shown in Appendix Table 7. The regression model for Calcium content was represented in (Equation. 22) as indicated in quadratic model with four variables

$$\text{Calcium} = -219\text{A} - 5071\text{B} - 3411\text{C} + 5005\text{D} + 8424\text{AB} + 4702\text{AC} - 6059\text{AD} + 1009\text{BC} \ldots\ldots \text{Equation (22)}$$

Where: A = QPM, B = Anchote, C = Carrot and D = Soybean

The Calcium contents of the seventeen formulations ranged from 101.69 -204.80 mg/100g (Table 8). The highest Calcium content was observed from a porridge formulation with blending proportion of 45% QPM, 20% *Anchote*, 15% carrot, and 20% soybean (Table 8). As evidenced from the contour plot, an increase in the blending proportion of *Anchote* and soybean flour resulted in simultaneous increase in the calcium content of the porridge samples (Figure 5a). This observation of high calcium content in porridge samples might result from the high calcium content in *Anchote* and soybean flour. A similar result was reported by EPHI, (1997) where high calcium content (119 mg/100g) was found in *Anchote* tuber. Also was reported by Habtamu, (2014) in with 115.7mg/100g of calcium content determined in *Anchote* tuber. Similar, result reported by Ndife *et al.* (2011) in soybean fortified breads increased the content of Calcium due to high mineral content of soybean flour. However, calcium content of porridge samples in this study declined with an increase in the blending proportion of QPM and carrot flour (Figure 5a). Similar observation was also reported by Shiriki (2014) where the calcium content of complementary food formulated from maize, soybean and peanut, decreased when the proportion of maize flour increased in the formulation. Carrot and root crops have low mineral contents as compared to other ingredients (Gocmen *et al.,* 2015).

The lowest Calcium content was determined in porridge samples prepared from the formulation composed of 85 % QPM, 10% *Anchote*, 5% carrot. This is another evidence to confirm that soybean is composed of high Calcium content i.e. exclusion of soybean flour from the formulation resulted in dramatic decline in the Calcium content of the formulation (excluded soybean). Ghavidel and Davoodi (2011) reported that the addition of legumes to cereal products increases their mineral contents. Calcium is a mineral required by the body for a variety of physiological functions and the maintenance of bone tissues throughout life (Broadus, 1996). Hence, *Anchote* flours is a good source of calcium and it helps in fast repairing of broken/ fracture bones and displaced joints, as it contains high Calcium content than other wide spread root and tuber crops (Endashaw, 2007). Therefore blends of *Anchote* flour in porridge prepared for children under the age of five years helps to reduce calcium deficiency. The Recommended Daily Allowance (RDA) of Calcium content for 6 to 59 months children is > 500 mg/day (Food and Nutrition Board, 2005).

4.4.2. Iron content

The Iron content of the ingredients: QPM, *Anchote*, carrot, and soybean flours were 3.61, 6.5, 1.63, and 7.12 mg per 100g respectively (Table 8). The effect of each ingredient on the Iron content p-values showed non-interaction effect of the ingredients ($P>0.05$) in formulations for (QPM, *Anchote*, carrot, and soybean) (Appendix Table 3). However, the iron content when increased the level of *Anchote* and soybean in composite flour increased. The adequacy of the model in predicting the experimental result (Iron content) of the formulation is checked and found to be acceptable based on the value of $R^2 = 92.16\%$ is confirmed which enables us to consider the models as good fit for predicting the Iron content where as in this study. The fitted quadratic regression model for Iron content is shown in Appendix Table 7. The regression model for Iron content was represented in (Equation. 23) as indicated in quadratic model with four variables

$$\text{Iron} = 4.23\text{A} + 11.29\text{B} - 42.29\text{C} + 36.05\text{D} - 5.96\text{AB} + 63.34\text{AC} - 40.51\text{AD} + 48.44\text{BC} \ldots\ldots\text{Equation (23)}$$

Where: A = QPM, B = Anchote, C = Carrot and D = Soybean

The Iron content of the porridge samples ranged from 5 - 6.99 mg/100g, and increased as the blending proportion of *Anchote* and soybean increased in the formulation (Figure 5b). *Anchote* and soybean improved the iron content of the porridge due to their high iron content in *Anchote* (Fikadu, 2013) and soybean flour (Tinsley, 2009). The iron content of the porridges increased from 16.9 to 21.6 mg/100g; the composition of iron increased as the proportion of soybean flour ratio increased in the formulations (Tirhas *et al.*, 2015). In this study blends QPM and carrot it reduced the iron content of the porridge than Anchote and soybean flour. Moreover, Jan *et al*. (2002) also reported that oilseeds flour contained appreciable quantity of iron, which will improve the mineral contents of composite flours in food product formulation. In the result study, porridge made from the blend proportion of 55% QPM, 20% *Anchote*, 5% carrot and 20% soybean flour contains the highest (6.99 mg/100g) Iron content. This amount of iron content cannot fulfill the Recommended Daily Allowance (RDA) of Iron for children under age of five which was reported to be 16 mg/100g (FAO, 2004). The Iron content in this study was in the range of 5-6.99mg/100gm which cannot fulfill the RDA. Therefore, Infants and children under the age of five if taken enough amount of Iron content by using other Iron source flour in complementary foods it reduces iron deficiency anemia (Britton *et al*, 2009).

4.4.3. Zinc content

The Zinc content of the ingredients: QPM, *Anchote*, carrot, and soybean flour were 2.27, 2.8, 1.4, 4.1mg/100g as shown in Table 8. The concentration of zinc in the ingredients was in the range of 2.2 to 3.25 mg/100gm, which is in close agreement with RDA of 3 mg/100g (FAO/WHO, 2004). The effect of each ingredient on the Zinc content in formulations (QPM, *Anchote*, carrot, and soybean) shows non-interaction effect of the ingredients (P>0.05) (Appendix Table 3). The adequacy of the model in predicting the experimental result (Zinc content) of the formulation is checked and found to be satisfactory based on the value of R^2= 90.73% and normality test P>0.05 is confirmed which enables us to consider the models as good fit for predicting the Zinc content in this study. The fitted quadratic regression model for Zinc content is shown in Appendix Table 7. The regression model for Zinc content was presented in (Equation. 24) as indicated in quadratic model with four variables

$$\mathrm{Zinc} = 2.61\mathrm{A} - 3.99\mathrm{B} - 17.68\mathrm{C} + 15.74\mathrm{D} + 3.31\mathrm{AB} + 17.91\mathrm{AC} - 15.56\mathrm{AD} + 73.83\mathrm{BC} \ldots\ldots\ldots\ldots\ldots\ldots \text{Equation (24)}$$

Where: A = QPM, B = Anchote, C = Carrot and D = Soybean

The highest value of 3.25 mg/100 g Zinc was recorded in the porridge sample made from a composite flour of 45% QPM, 20% *Anchote*, 15% carrot and 20% soybean flour (Table 8). The study showed that the concentration of zinc increased with simultaneous increase in *anchote* and soybean flour than QPM and carrot flour in the blending proportion as indicated in the contour plot (Figure 5c). The result in this study is in agreement with Karkle and Beleia (2010) and Shemelis (2009), using soybean with QPM flours in food formulation will improve Zinc content of porridge due to soybean. Therefore, zinc contents for under age of five children to tackle the malnutrition problem that might arise from zinc deficiency (Sahra and Mwangi, 2008).

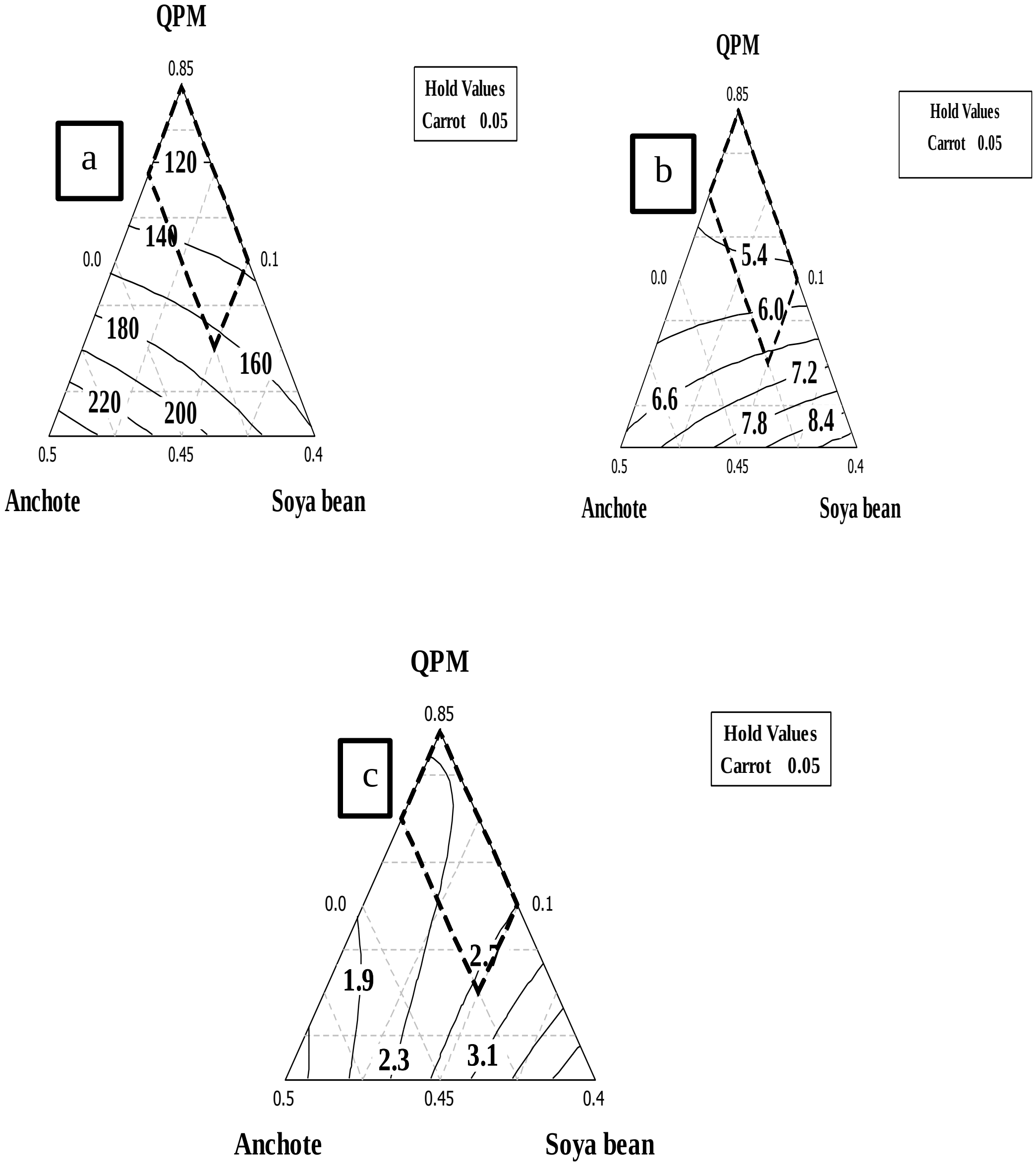

Figure 5: Contour plots of (a) Calcium (b) Iron and (c) Zinc content of porridge holding carrot constant at 5%

Table 9: Mean values of beta carotene content for porridge and individual flours

	Components				**Beta carotene content (** μg/100g)
Run	A	B	C	D	Beta carotene
CF1	0.85	0.1	0.05	0	1511
CF2	0.45	0.2	0.15	0.2	2200
CF3	0.65	0.1	0.05	0.2	1165
CF4	0.55	0.2	0.05	0.2	1269
CF5	0.75	0.2	0.05	0	1229
CF6	0.55	0.1	0.15	0.2	2215
CF7	0.75	0.1	0.15	0	2148
CF8	0.65	0.2	0.15	0	2197
CF9	0.65	0.15	0.1	0.1	1727
CF10	0.75	0.125	0.075	0.05	1617
CF11	0.55	0.175	0.125	0.15	1938
CF12	0.65	0.125	0.075	0.15	1566
CF13	0.6	0.175	0.075	0.15	1589
CF14	0.7	0.175	0.075	0.05	1576
CF15	0.6	0.125	0.125	0.15	1992
CF16	0.70	0.125	0.125	0.05	2000
CF17	0.65	0.175	0.125	0.05	2050
A	100	-	-	-	280.46
B	-	100	-	-	204.82
C	-	-	100	-	4582.1
D	-	-	-	100	224.49

Where; CF= complementary food, A= QPM, B= *anchote*, C= carrot, D= Soybean

4.5. Beta Carotene Content

The mean β-carotene content of QPM, *Anchote*, carrot and soybean were 280.46, 204.819, 4582.1 and 224.491 μg/100g respectively. The adequacy of the model in predicting the experimental result (β-carotene content) of the formulation was found to be satisfactory based on the value of R^2 = 97.90%, Normality test, ($P > 0.05$) is confirmed which enables us to consider the models as good fit for predicting the beta carotene content in linear and quadratic in this study. The fitted quadratic regression model for beta carotene content is shown in Appendix Table 7.The regression model for beta carotene content was presented in (Equation. 25) as indicated in quadratic model with four variables

$$\text{Beta carotene } = 1975\text{A} + 17216\text{B} + 29011\text{C} - 14175\text{D} - 24713\text{AB} - 25737\text{AC} + 17372\text{AD} - 40309\text{BC} \ldots\ldots \text{Equation (25)}$$

Where: A = QPM, B = Anchote, C = Carrot and D = Soybean

The Beta-carotene content of the porridges ranged from 1165 to 2215 μg/100 g (Table 9). The interaction effect of QPM and carrot flour addition was found to be significant ($P<0.05$) on beta carotene content of porridge samples (Appendix Table 3). The highest beta carotene content (2215μg/100g) corresponded to the porridge sample containing high proportion of carrot, with blending ratio of 55% QPM, 10% *Anchote*, 15% carrot and 20% soybean flour. The β-carotene content of porridge sample increased with an increase in the blending ratio of carrot as indicated by the contour plot (Figure 6).

In support of the result of β-carotene content recorded Gocmem *et al*. (2015) reported that carrot is good source of vitamin A as 85- 97% of total carotenoid in carrot is beta-carotene and also amount of beta carotene content of carrot were 4930μg/100g. In current results finding contradict result reported by Beruk *et al.* (2015) who reported that complementary food formulation from QPM, chick pea OFSP and Teff the amount of beta carotene content was (291.63 to 565.09 μg/100gm). This variation might be due to blends of carrot it increased the beta carotene content of porridge. Hence, utilization of carrot flour in complementary food formulation can be taken as promising strategy to tackle the challenge of vitamin A deficiency with a high prevalence rate among infants and young children (Baljeet *et al.*, 2014).

According to WHO/FAO/UNICEF (2016), the amount of beta carotene supplementation to fulfill the Recommended Daily Allowance is 400 µg RAE vitamin A for under age of five children. Thus, 2 µg of beta carotene content equal to 1 µg RAE vitamin A; in this study, beta carotene ranged (582.5-1107.5µgRAE) which is more than the RDA. This higher result found might be in addition to carrot flour the other ingredients of QPM, Anchote and soybean flour it contributed to increase the beta carotene content of the porridge; due to this finally it increased the beta carotene content of the porridge. The least β-carotene content (1165 μg/100), however, corresponds to the porridge sample prepared from the formulation containing the lowest proportion of carrot powder (QPM, *Anchote,* carrot and soybean , 65, 10, 5 and 20%).

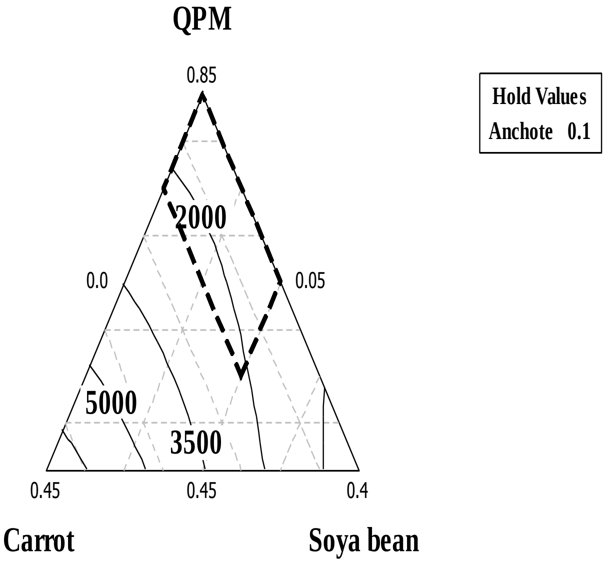

Figure 6: Contour plots of beta-carotene content of porridge holding *Anchote* at constant value of 10%

4.6. Anti-nutritional Factors

The mean values of phytate and tannin contents of porridges are presented in Table 9. The effect of ingredients used in the formulation (QPM, *anchote*, carrot, soybean flour) on the contents of phytate and tannin on the porridge were analyzed using ANOVA and p-values for the fitness of the model in predicting the anti-nutritional contents and interaction of ingredients are summarized in Appendix Table 1. Anti-nutritional factors analysis and fitted regression coefficients of individual and formulated product of phytate and tannin content are summarized in Appendix Table 5.

Table 10: Mean values of anti-nutritional factors for porridge and individual flour

Components					**Anti-nutritional factors (mg/100g)**	
Run	A	B	C	D	Phytate	Tannin
CF1	0.85	0.1	0.05	0	82.99	13.89
CF2	0.45	0.2	0.15	0.2	96.50	14.66
CF3	0.65	0.1	0.05	0.2	97.31	11.85
CF4	0.55	0.2	0.05	0.2	95.70	14.78
CF5	0.75	0.2	0.05	0	96.50	12.17
CF6	0.55	0.1	0.15	0.2	93.31	10.6
CF7	0.75	0.1	0.15	0	82.71	8.92
CF8	0.65	0.2	0.15	0	80.58	11.5
CF9	0.65	0.15	0.1	0.1	88.21	10.27
CF10	0.75	0.125	0.075	0.05	87.11	10.94
CF11	0.55	0.175	0.125	0.15	96.18	9.4
CF12	0.65	0.125	0.075	0.15	96.21	8.98
CF13	0.6	0.175	0.075	0.15	96.24	10.4
CF14	0.7	0.175	0.075	0.05	87.16	10.56
CF15	0.6	0.125	0.125	0.15	96.34	10.1
CF16	0.7	0.125	0.125	0.05	85.20	9.27
CF17	0.65	0.175	0.125	0.05	89.12	9.28
A	100	-	-	-	110.08	11.17
B	-	100	-	-	109.35	56.14
C	-	-	100	-	9.52	3.79
D	-	-	-	100	123.34	32.23

A= Quality protein maize= B= *Anchote* = C=Carrot =D = Soybean = CF= complementary food

4.6.1. Phytate content

The mean values of phytate content of the ingredients were 110.08, 109.35, 59.5 and 123.34 mg/100g for QPM, *Anchote*, carrot, and soybean, respectively (Table 10). The effect of each ingredient on the phytate content in formulations (QPM, *Anchote*, carrot, and soybean) shows non-interaction effect of the ingredients (P>0.05) in Appendix Table 1. The adequacy of the model in predicting the experimental result (phytate content) of the formulation is checked and found to be satisfactory based on the value of (R^2= 80.23%) and normality test P>0.05 is confirmed which allows us to consider the models as good fit for predicting the phytate content both in linear and quadratic components of the regression model of the composition of phytate content in the product were significantly influenced by QPM, Anchote and soybean proportion except carrot flour in this study. The regression model for phytate content was represented in (Equation. 26) as indicated in quadratic model with four variables

$$\text{Phytate} = 77.1\text{A} + 84.4\text{B} + 418.2\text{C} + 47.4\text{D} + 135.3\text{AB} - 425.4\text{AC} + 119.4\text{AD} - 757\text{BC} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{Equation (26)}$$

Where: A = QPM, B = Anchote, C = Carrot and D = Soybean

The phytate content of the porridge samples ranged from 80.58 to 97.31mg/100g (Table 10). However phytate content of porridges samples increased when the proportion ratio of QPM, *Anchote* and soybean flour increased in the composite flour (Figure 7a). The highest phytate content 97.31mg/100g was recorded in a porridge sample prepared from the formulation containing 65% QPM, 10% *Anchote*, 5% carrot and soybean 20%. Similar results were Meseret (2011) where QPM had high phytate content 249mg/100g. According to Habtamu (2014), phytate content (333-389mg/100g) was found in *Anchote* flour Liener, (2000) in soybean flour.

High phytate content in foods Phytate binds divalent cations and forms a complex with protein and reduce the bioavailability of those nutrients (Hussain, 2011; Vasagam and Rajkumar, 2011). Phytic acid is heat-stable, but can be reduced by soaking, germination and/or fermentation (Muzquiz and Wood, 2007). The lowest phytate content was measured in a porridge made from high proportion ratio of carrot flour; QPM: 65%, *Anchote*: 20%, carrot 15%, and soybean 0%. This is mainly because of an increase in ratio of carrot flour which is low in phytate content (Table 10). Rashidi, (2011) reported that low phytate content is important for porridge prepared for target groups; to increase the availability of nutrient in porridges. In addition, pre-processing methods like soaking and germination can reduce anti-nutritional content of cereal and legumes grains due to activation of endogenous phytate enzyme and leaching of phytate into soaking water (Radzi *et al*., 2012; Beruk *et al*., 2015).

4.6.2. Tannin content

Tannin content of the blends is summarized in Table 10. The interaction effect of QPM with soybean and *Anchote* with carrot flour blending proportion was significant ($P<0.05$) in the tannin content of porridge samples of both linear and quadratic models (Appendix Table 1). The mean values of tannin content of the ingredients are 11.17, 56.14, 3.79, and 32.23 mg/100g for QPM, *Anchote*, carrot, and soybean respectively (Table 10). The acceptability of the model in predicting the experimental results (tannin content) of the formulation is checked and found to be satisfactory based on the value of $R^2 = 86.61\%$ normality test, ($P>0.05$) is confirmed which enables us to consider the models as good fit for predicting the tannin content both in linear and quadratic components of the regression model of the composition of tannin content in the product were significantly influenced by *Anchote* and soybean proportion in this study. The regression model for tannin content was represented in (Equation. 27) as indicated in quadratic model with four variables

$$\text{Tannin} = 9.3A - 229B - 326C + 346.8D + 308.2AB + 340.3AC - 458AD + 883.7BC \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{Equation (27)}$$

Where: A = QPM, B = Anchote, C = Carrot and D = Soybean

Tannin content of porridge samples prepared from the formulations varied from 8.92 to 14.66 mg/100g (Table 10). The highest tannin content was recorded when higher proportions of soybean and *Anchote* were used (QPM, *Anchote*, carrot and soybean: 45, 20, 15, and 20% respectively). Figure 7b indicates that tannin content of the porridge samples increased with the simultaneous increases in the blending proportion of soybean and *Anchote* in composite flour. This might be due to the high tannin content in *Anchote* and soybean flours. Similar result was also reported by Meseret (2011) high tannin content (121 mg/100g) in soybean flour. Habtamu (2014) also found high tannin content (102.36 - 173.55mg/100g) in *Anchote* tuber. Hence, different processing methods such as soaking, blanching, roasting and cooking have been reported by many researchers to reduce the effect of tannin content and improve the bioavailability of nutrient content of legume seeds (Mohamed *et al.*, 2010; Sokrab *et al.*, 2012).

In this study, the lowest tannin content was found when the proportion *Anchote* and soybean was minimum (QPM, *Anchote*, carrot, and soybean were 75, 10, 15 and 0%, respectively). High proportion of carrot decreased the tannin content of the porridge because carrot had low anti-nutritional content (Baljeet *et al.,* 2014). Therefore, low tannin content is important for porridge prepared for target groups.

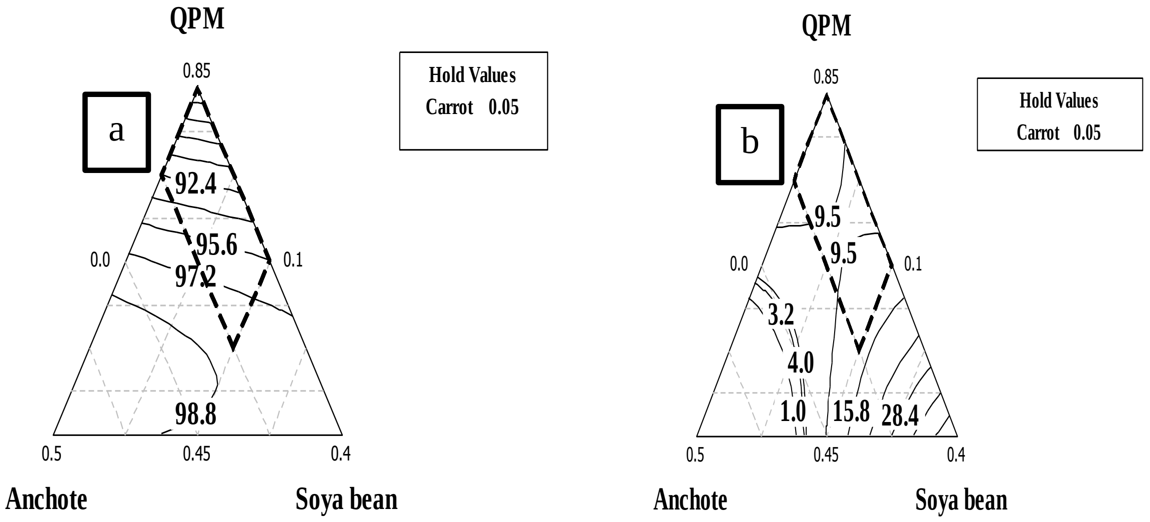

Figure 7: Contour plots of (a) Phytate and (b) tannin content of porridge holding carrot constant at 5%

4.7. Molar ratio and bioavailability of minerals

4.7.1. Phytate: calcium ratio

The molar ratios of phytate/mineral of all porridge samples are calculated and presented (Table 10). Phytic acids markedly decrease calcium bioavailability and the Phytate: Ca molar ratio has been proposed as an indicator of its bioavailability. The critical molar ratio of Phytate: Calcium is 0.17mol (Morris and Ellis 1985). In present study, all porridge samples had phytate: Calcium molar ratios of less than 0.17mol (Table 11). This indicates that Calcium is bioavailable to support calcium requirement of children.

4.7.2. Phytate: iron ratio

Table 8 indicated the mineral content in all food samples while, the molar ratios of phytate/mineral of all food samples are summarized and shown in Table 11. Iron molar ratio has to be lower than 1 to obtain a significant increase in Iron absorption (Hurell, 2004). With regard, to the present study, all porridge samples had phytate: iron molar ratios greater than 1 which indicates limited bioavailability of Iron (Table 11). This might be because of the high content of phytate in porridge samples which affects the mineral bioavailability of these foods. To alleviate, the Iron deficiency, the formulations developed in this study should be supplemented with other Iron rich sources food, like Teff.

4.7.3. Phytate: zinc ratio

The importance of a foodstuff as a source of dietary Zinc depends on both the total Zinc content and the level of other anti-nutrients in the diet that affect Zinc bioavailability. The phytate: Zinc molar ratio is considered as a better indicator of Zinc bioavailability than total dietary phytate levels alone (Oberleas and Harland, 1983). All the porridge samples formulated had low Phytate: Zinc values which is less than the critical value of 5 (Oberleas and Harland, 1983). This indicates that, Zinc bioavailability will not be affected the porridge.

Table 11: Calculated molar ratio of quality protein maize based porridge (mol)

Run	A	B	C	D	Phytate (mg/100g)	Phy (mol)	**(a)** Phy:Ca	**(b)** Phy: Fe	**(c)** Phy: Zn
CF1	0.85	0.1	0.05	0	82.99	0.08	0.01	1.61	0.03
CF2	0.45	0.2	0.15	0.2	96.50	0.10	0.02	1.04	0.05
CF3	0.65	0.1	0.05	0.2	97.31	0.10	0.03	1.41	0.04
CF4	0.55	0.2	0.05	0.2	95.70	0.10	0.03	1.12	0.04
CF5	0.75	0.2	0.05	0	96.50	0.10	0.05	1.59	0.03
CF6	0.55	0.1	0.15	0.2	93.31	0.09	0.02	1.23	0.04
CF7	0.75	0.1	0.15	0	82.71	0.08	0.05	1.52	0.03
CF8	0.65	0.2	0.15	0	80.58	0.08	0.03	1.45	0.04
CF9	0.65	0.15	0.1	0.1	88.21	0.09	0.04	1.54	0.03
CF10	0.75	0.13	0.08	0.05	87.11	0.09	0.04	1.52	0.04
CF11	0.55	0.18	0.13	0.15	96.18	0.10	0.03	1.38	0.04
CF12	0.65	0.13	0.08	0.15	96.21	0.10	0.04	1.44	0.04
CF13	0.6	0.18	0.08	0.15	96.24	0.10	0.04	1.44	0.04
CF14	0.7	0.18	0.08	0.05	87.16	0.09	0.04	1.48	0.04
CF15	0.6	0.13	0.13	0.15	96.34	0.10	0.04	1.47	0.04
CF16	0.7	0.13	0.13	0.05	85.20	0.09	0.04	1.51	0.04
CF17	0.65	0.18	0.13	0.05	89.12	0.09	0.04	1.61	0.04
A	100	-	-	-	110.08	0.11	0.16	4.9	0.05
B	-	100	-	-	109.35	0.11	0.09	2.2	0.03
C	-	-	100	-	9.52	0.01	0.01	0.4	0.03
D	-	-	-	100	123.34	0.12	0.01	0.5	0.06

A= Quality protein maize B= Anchote C= Carrot D= Soybean CF= complementary food

MW= molecular weight **(a)** mg of Phytate/MW of Phytate: mg of Calcium/MW of Calcium

(**b)** mg of Phytate/MW of Phytate: mg of Iron/MW of Iron

(**c)** mg of phytate/MW of phytate: mg of Zinc/MW of Zinc

4.8.Sensory Properties of Porridge Samples

The mean consumer scores of porridge samples prepared from composite flour of QPM, *Anchote*, carrot and soybean flour are presented in Table 12. The blending ratio of ingredients significantly (P<0.05) affected the consumer score for acceptability of sensory properties of the porridge samples as described both by linear and quadratic models (Appendix Table 4). Non-significant effect on normality test also ensured that both models can be used to predict the sensory qualities of porridge samples. Estimated regression coefficient for the sensory scores of porridge samples with various blending ratios are summarized in (Appendix Table 8).

Table 12: Mean consumer scores for acceptability sensory quality parameters of porridge

	Components				**Average scales for Sensorial quality**				
Run	A	B	C	D	Color	Aroma	Taste	MF	OA
Cf1	0.85	0.1	0.05	0	3.10	3.98	3.51	3.51	3.50
Cf2	0.45	0.2	0.15	0.2	4.50	4.79	4.70	4.81	4.78
Cf3	0.65	0.1	0.05	0.2	3.05	3.55	3.28	3.55	3.02
Cf4	0.55	0.2	0.05	0.2	3.80	3.94	3.68	3.54	3.82
Cf5	0.75	0.2	0.05	0	4.24	4.19	3.73	3.19	4.26
Cf6	0.55	0.1	0.15	0.2	4.77	4.76	4.80	4.74	4.22
Cf7	0.75	0.1	0.15	0	3.04	3.95	3.48	3.95	3.02
Cf8	0.65	0.2	0.15	0	3.21	3.67	3.43	3.67	3.20
Cf9	0.65	0.15	0.1	0.1	3.52	3.73	3.61	3.73	3.50
Cf10	0.75	0.125	0.075	0.05	3.54	3.65	3.57	3.65	3.50
Cf11	0.55	0.175	0.125	0.15	4.45	4.35	4.39	4.35	4.44
Cf12	0.65	0.125	0.075	0.15	3.52	3.55	3.52	3.55	3.50
Cf13	0.6	0.175	0.075	0.15	3.53	3.57	3.53	3.57	3.50
Cf14	0.7	0.175	0.075	0.05	3.50	3.45	3.52	3.45	3.60
Cf15	0.6	0.125	0.125	0.15	4.00	3.98	4.00	3.98	4.02
Cf16	0.7	0.125	0.125	0.05	3.11	3.36	3.18	3.36	3.00
Cf17	0.65	0.175	0.125	0.05	3.18	3.55	3.40	3.55	3.26

A= quality protein maize, B= Anchote, C= carrot, D= Soybean, CF= complementary food MF= mouth feel, OA= overall acceptability

4.8.1. Color

The mean consumer score for color acceptability of QPM based porridge supplemented with *Anchote*, carrot and soybean flour are summarized in Table 12. The model capability in predicting the experimental results (color acceptability) of the formulation was checked by normality test (P> 0.05) (R^2 value= 90.2%) and found to be acceptable. The regression model for color acceptability was represented in (Equation. 28) as indicated in quadratic model with four variables

$$\text{Color} = 2.4\text{A} + 10.3\text{B} + 91.6\text{C} - 7.1\text{D} + 9.3\text{AB} - 102.9\text{AC} + 7.7\text{AD} - 180.7\text{BC} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{Equation (28)}$$

Where: A = QPM, B = Anchote, C = Carrot and D = Soybean

The sensory scores of color for the porridge samples ranged from 3.1-4.77. Moreover, ANOVA shows that the interaction effect of QPM and carrot flours on porridge color was significant (P<0.05) in both linear and quadratic models. The contour plot indicated that the acceptability of color increased with increasing level of carrot in composite flours (Figure 8). It was noted that panelists preferred most porridge color prepared by blending the composites in the proportion of 55 % QPM, 10 % *Anchote,* 15 % carrot, and 20 % soybean flour (Table 12). This formulation is among the treatments with relatively higher proportion of carrot flour. Increasing the proportion of carrot powder in the formulation increased the color appreciation of the panelists (Table 12). This could be attributed to the consumer preference for to orange color of the porridge. Similar result was reported by Rakcejeva *et al.* (2012). The color of this product is bright orange due to the high amount of carrot and soybean flour and the low amount of QPM and *Anchote* flour.

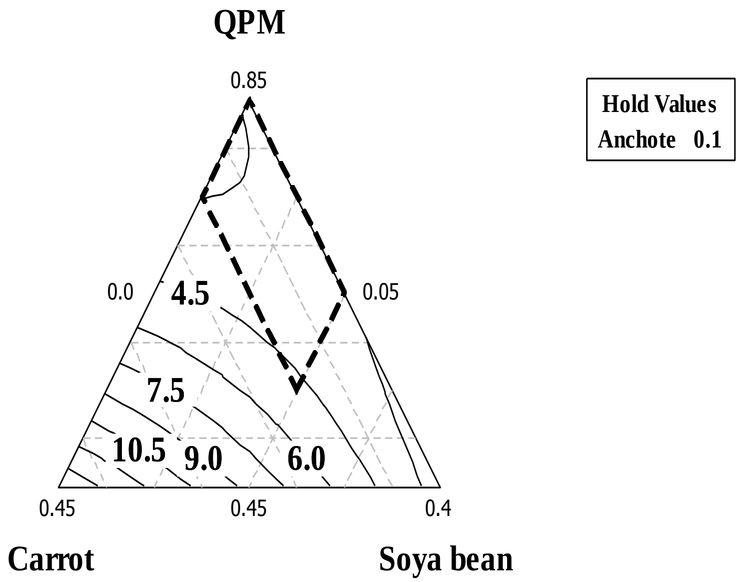

Figure 8: Contour plots of color acceptability of porridge holding *Anchote* constant at 10%

The least preferred color of the porridge was a color from porridge developed by blending the composites in the proportion of 85% QPM, 10% *Anchote*, 5% carrot, and 0% soybean flour. The acceptability of color declined with decrease in proportion of carrot and soybean in composite flour. The consumers' color acceptability scores recorded in this study are in agreement with those of Parvinder *et al*. (2015) when carrot powder has an importance in increasing the color appreciation of consumers when using carrot powder as an ingredient in formulation of foods. Rakcejeva *et al*. (2012) also stressed that, carrot is an important vegetable crop and it improves color of diets across the world.

4.8.2. Aroma

The mean consumer score for aroma acceptability of seventeen formulations of porridge samples ranged from 3.36 to 4.79 (Table 12). The interaction effect of flour of QPM and soybean on the aroma of the porridge samples was significant ($P<0.05$) in linear and quadratic models. The model appropriateness in predicting the experimental results (aroma acceptability) of the formulation was checked by normality test ($P> 0.05$) (R^2 value= 90.1%)

and found to be acceptable. The regression model for aroma acceptability was represented in (Equation. 29) as indicated in quadratic model with four variables

$$\text{Aroma} = 2.86\text{A} - 28.1\text{B} + 10.6\text{C} + 45.48\text{D} - 48.24\text{AB} - 7.52\text{AC} - 62.12\text{AD} + 9.42\text{BC} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{Equation (29)}$$

Where: A = QPM, B = Anchote, C = Carrot and D = Soybean

The highest mean consumer score for aroma acceptability was recorded from porridge sample prepared by blending the composites in the proportion of 45% QPM, 20% *Anchote*, 15% carrot and 20% soybean flour. This is marked from contour plot which shows that, as the roasted soybean flour proportion increased in the formulation, the aroma acceptability has increased (Figure 9). This might be associated with inactivation of lipoxygenase enzyme in soybean (Li *et al.*, 2008).

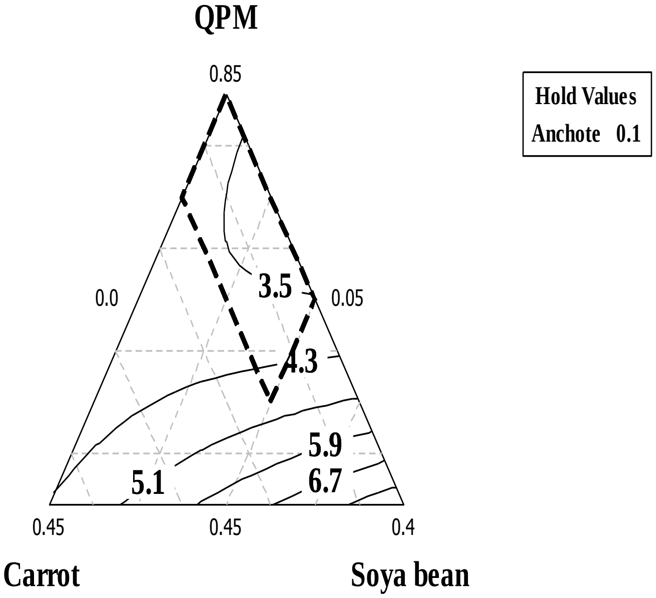

Figure 9: Contour plots of aroma acceptability of porridge holding *Anchote* constant at 10%

Beany flavor is related to lipoxygenase and is undesirable and greatly reduces the acceptability of products containing soybean (Bott and Chambers, 2006). However different processing methods such as heat treatments and addition of flavor compounds have been suggested to reduce the beany flavor (Charles *et al.*, 2014). Oladele *et al*. (2009) roasted legumes induce more attractive aroma to while using them in preparation of porridge as compared to raw legumes which might be related to the release of inherent aromatic compounds found as a result of heat treatment during roasting.

Charles *et al.(*2014) reported that aroma of porridge prepared from yam, cowpea and soybean was preferred by consumer panelist due to roasted soybean. According to Muhimbula *et al*. (2011) aroma is an integral part of taste and influences the general acceptance of the food before it is put in the mouth. The least mean score of aroma was recorded in porridge samples prepared by formulating the composites in the proportion of 70% QPM, 12.5% *Anchote*, 12.5% carrot, and 5% soybean flour. The mean acceptability score of porridge aroma decreased with increasing proportion of QPM and *Anchote* flours in the formulation. The result clearly shows that increasing the proportion of QPM and *Anchote* flour is not a good choice to develop porridge with more acceptable aroma.

4.8.3. Taste

The interaction effect of QPM and carrot on taste was significant ($P<0.05$) both in linear and quadratic models. The mean consumer scores for the acceptability of the taste of porridge samples ranged from 3.18 to 4.8 (Table 12). Porridge samples prepared from the blending proportion of 55% QPM, 10% *Anchote*, 15% carrot and 20% soybean flour received the highest taste score by consumer panels (Table 12). The model adequacy in predicting the experimental results (taste acceptability) of the formulation was checked by normality test ($P> 0.05$) (R^2 value= 91.3%) and found to be acceptable. The regression model for taste was represented in (Equation. 30) as indicated in quadratic model with four variables

$$\text{Taste} = 3.7\text{A} + 5.96\text{B} + 62.4\text{C} + 3.7\text{D} - 2.3\text{AB} - 71\text{AC} - 6.6\text{AD} - 97.2\text{BC} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{Equation. } 30$$

Where: A = QPM, B = Anchote, C = Carrot and D = Soybean

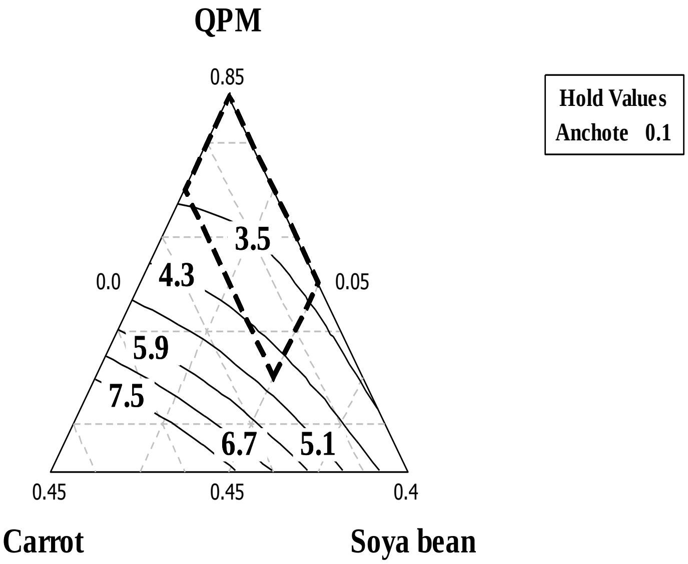

Figure 10: Contour plots of taste acceptability of porridge holding *Anchote* constant at 10%

Graphical optimization of consumer taste score of porridge samples through contour plot indicates that acceptability of taste increases with an increase in the proportion of carrot flour (Figure 10). This might be due to the sweeter characteristics of carrot flour as compared to other ingredients in the formulation (Rakcejeva *et al.,* 2012).

Similar observation was reported by Baljeet *et al.* (2014) when biscuit prepared from chickpea and carrot flour had increased taste acceptance with increased proportion of carrot in the blend. Taste is one of the important sensory quality parameters of complementary foods. It is attributes consist of saltiness, sweetness, bitterness and acidity, which is detected by the taste buds at the tip, sides, and back of the tongue respectively. It is one of the important sensory quality parameters of a food product. The least consumer taste score in this blend was recorded in the porridge sample prepared from the formulation comprising of 70% QPM, 12.5% *Anchote*, 12.5% carrot and 5% soybean flour. It is observed that higher blending proportion of QPM has not preferred by panelist, this might be due to the germinated of QPM which slightly affected the taste of porridge. According to Beruk *et al.,* (2015) complementary food prepared from germinated QPM, chick pea, OFSP and Teff; it improves the nutrient content of the product but reduced the sensory quality of the final products.

4.8.4. Mouth feel

The mean consumer mouth-feel score of porridge was not significantly (p>0.05) affected by the ingredients; however, there was a trend that carrot and soybean flours influence mouth feel than QPM and *Anchote* flour (Table 12). The model adequacy in predicting the experimental results (mouth feel acceptability) of the formulation was checked by normality test (P> 0.05) (R^2 value= 91.3%) and found to be acceptable. The regression model for mouth feel was represented in (Equation. 31) as indicated in quadratic model with four variables

$$\text{Mouth feel } = 4.13\text{A} + 3.01\text{B} + 29.8\text{C} + 11.1\text{D} - 4\text{AB} - -30.59\text{AC} - 13.88\text{AD} - 20.24\text{BC} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\text{Equation (31)}$$

Where: A = QPM, B = Anchote, C = Carrot and D = Soybean

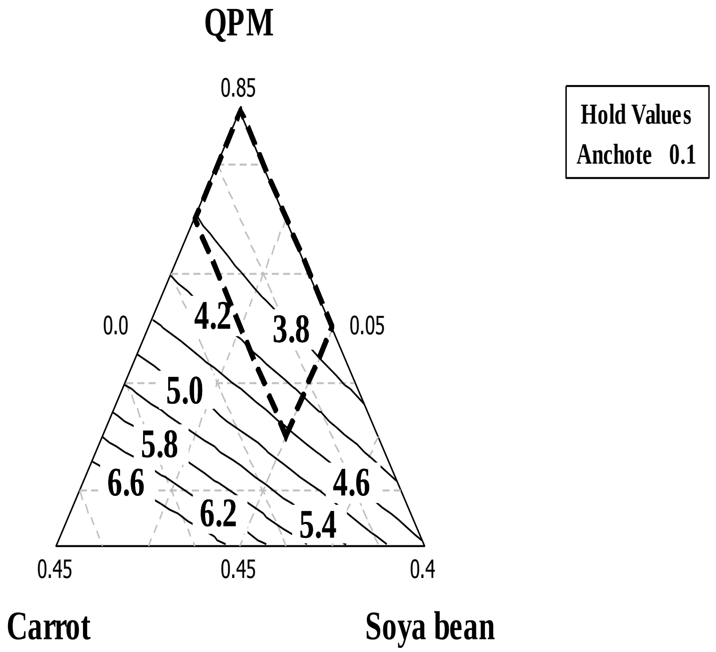

Figure 11: Contour plots of mouth feel acceptability of porridge holding *Anchote* at 10%

The highest consumer mouth-feel score (4.81) was observed in the porridge sample prepared from the formulation with the blending proportion of 45% QPM, 10% *Anchote*, 15% carrot, and 20% soybean flour. Mouth feel of the porridge increased with increasing proportion of carrot and soybean in the composite flour (Table 12). In this study carrot also shows better mouth feel acceptability of the porridge. The formulation consisting of 75% QPM, 20% *Anchote*, 5% carrot, and 0% soybean flour was the least liked by consumer and received a mean score value of 3.19 (Table 12). The contour plot shown in Figure 11 indicated that the acceptability of mouth feel declined with increasing proportion of QPM and *Anchote* than carrot and soybean flour., this might be negatively affected by processing like soaking and germination of quality protein maize based porridge. Similar results were observed in complementary porridges prepared from QPM, chickpea, OFSP and Teff (Beruk *et al.*, 2015).

4.8.5. Overall Acceptability

The interaction effect of QPM with carrot and *Anchote* with carrot flour blending ratio was significant ($P<0.05$) on the consumer score of overall acceptability of porridge samples both in linear and quadratic models (Appendix Table 4). The model acceptability in predicting the experimental results (overall acceptability) of the formulation was checked by normality test ($P> 0.05$) (R^2 value= 89.18%) and found to be acceptable. The regression model for overall acceptability was presented in (Equation. 32) as indicated in quadratic model with four variables

$$\text{Overall acceptability} = 4.6\text{A} + 32.9\text{B} + 97.1\text{C} - 19.5\text{D} - 29.6\text{AB} - 119\text{AC} + 19.3\text{AD} - 181\text{BC} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{Equation (32)}$$

Where: A = QPM, B = Anchote, C = Carrot and D = Soybean

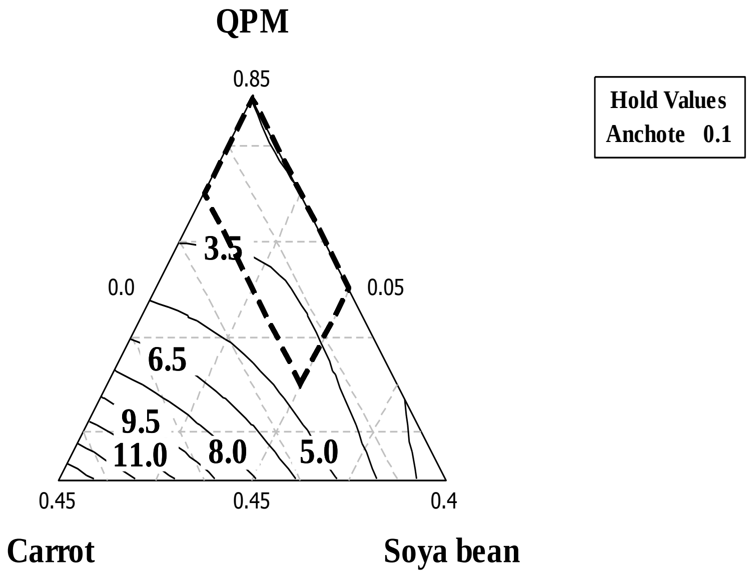

Figure 12: Contour plot of overall acceptability of porridge in mixture holding *Anchote 10%*

Porridge sample that received the highest (4.78) consumer overall acceptability score was prepared from the formulation composed of 45% QPM, 20% *Anchote*, 15% carrot, and 20% soybean flour. The contour plot shown in Figure 12 indicates that the consumer overall acceptability score of porridge increased in parallel with an increase in the proportion of carrot flour; as compared to the other ingredients (Table 12).

The lowest consumer overall acceptability score (3.00) were neither liked nor disliked when the porridge sample was prepared from the formulation with the blending proportion of 70% QPM, 12.5% *Anchote*,12.5% carrot, and 5% soybean flour. The mean consumer overall acceptability score reported in the present study confirmed that overall acceptance of porridge was inversely related to the proportion of QPM and *Anchote* flour in the formulation i.e. as the proportion of QPM and *Anchote* flour increased in the formula of porridge sample, overall acceptance of porridge will decrease. Lower overall acceptability of porridge might be related to poor sensory acceptability of germinated QPM. Similar investigation reported by Shimelis *et al*. (2009). Beruk *et al.* (2015) reported that porridges prepared from germinated cereal flours were slightly dark brown, had a bitter taste and a strong malt flavor and hence will have lower overall acceptability by consumer panels.

4.9. Regions of Optimum Mixture Composition

Regions of optimum mixture composition for each plot by using response optimizer, the white region shows the “optimum region” that optimizes the sensory attributes of interest.

4.9.1. Chemical composition

The optimum value for moisture, protein, ash, fat, carbohydrate and energy of QPM based porridge supplemented with *Anchote*, carrot and Soybean flour varied between 5 – 6%, 16 – 19%, 1.75 - 3.5%, 7 -9, 50 -65%, 370 - 390 kcal/100g respectively. These optimum values of nutrient composition were reported from the formulation with the blending ratio of 55% QPM, 10% *Anchote*, 15% carrot and 20% soybean flour as indicated by the sweet spot (white area) through overlaid contour plot (Figure 13).

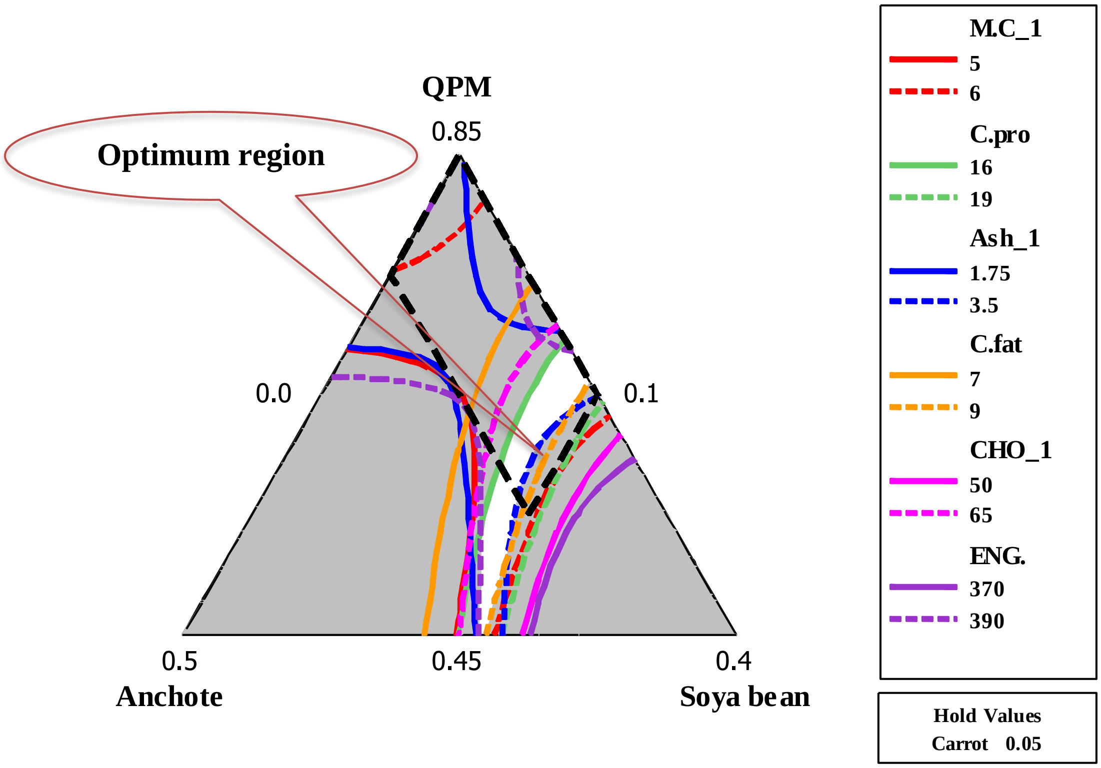

Figure 13: Overlaid contour plot of composite flours porridge proximate composition with carrot hold constant at 5%

4.9.2. Mineral content

The optimum value for Calcium, Iron and Zinc content of the porridge samples ranged between 100 - 200, 4 - 6, and 2- 3 mg/100g respectively as indicated by the sweet spot (Figure 14). These optimum values of nutrient composition for the porridge samples were reported from the formulation with a blending ratio of 45% QPM, 20% *Anchote*, 15% carrot and soybean 20% flour.

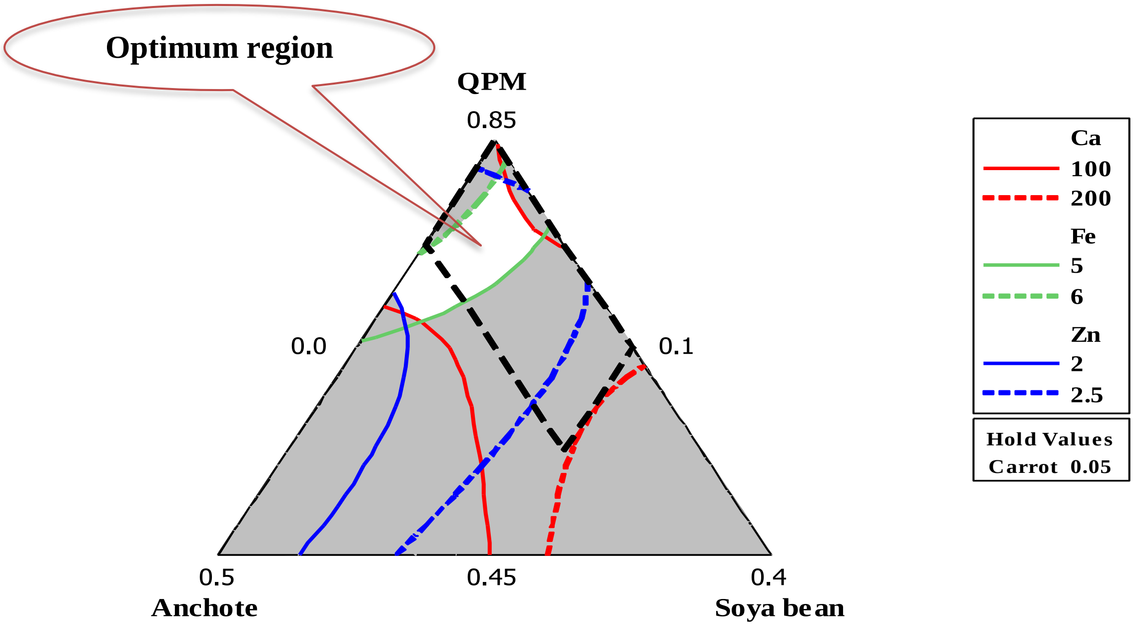

Figure 14: Overlaid contour plot of composite flours porridge of mineral content with carrot hold constant at 5%

4.9.3. Optimum point for sensory evaluation

Figure (15) overlaid contour plot showed the optimum region for sensory properties of the complementary food were optimized with optimization criteria of maximizing the sensory quality ratings of porridge. Accordingly, in the porridge samples prepared from the formulation comprising of 45% QPM, 20% *Anchote*, 15% carrot and 20% soybean flour, the optimum acceptability score for color, aroma, taste, mouth feel and overall acceptability ranged from 3.58 - 4.52, 4 - 4.5, 3.5 - 4.5, and 3- 4.78 respectively (Figure 15). In this experiment, we found that the addition of carrot increased acceptability by the panelists due to the color appreciation and sweetness that is induced. The study conducted by Muhimbula *et al*. (2011) have shown that complementary food formulations with addition of sugar were found to be more tasty and attractive than those without sugar by mothers and children.

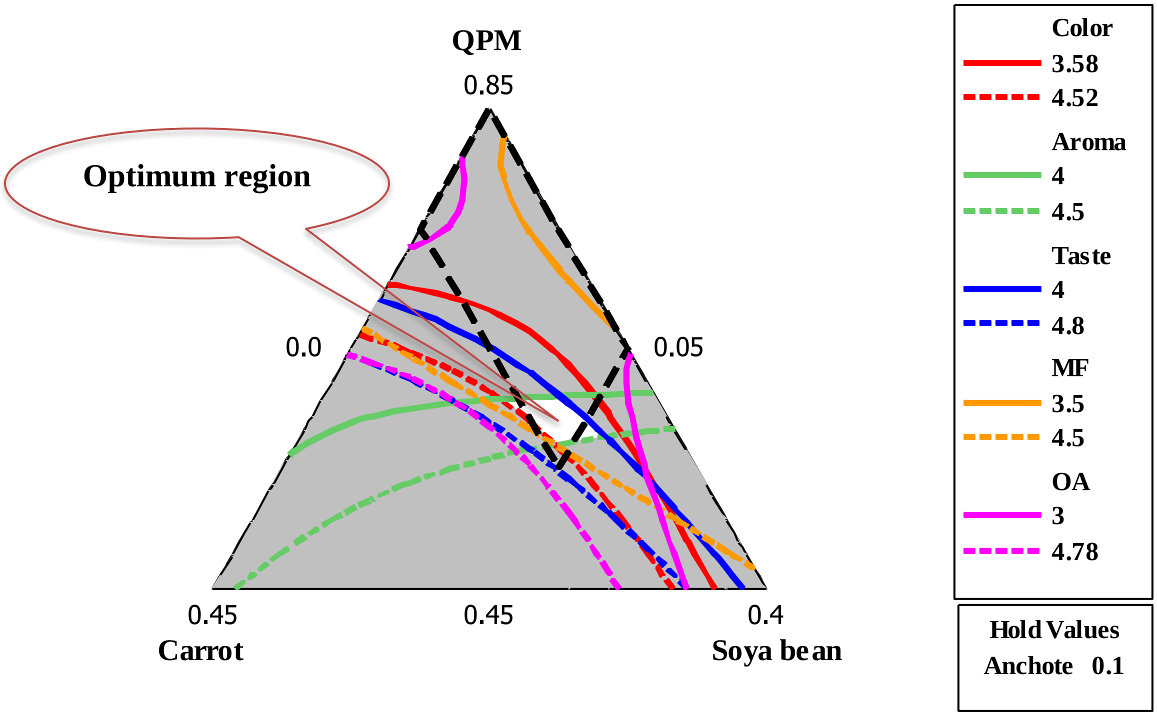

Figure 15: Overlaid contour plot of composite flours porridge sensory quality with *Anchote* hold constant at 10%

4.9.4. Optimum mixture compositions of porridge in nutritional and sensory qualities

This experiment focused on determining the optimum blending ratio of each ingredient to produce porridge with desirable nutrient compositions and sensory acceptability for the target group (children under the age of five years). The formulation with a blending ratio of (55%) maize, (10%) *Anchote*, (15%) carrot and soybean (20%) had the optimum value of protein, carbohydrate, energy, Calcium, beta carotene and the overall acceptability that varied between: 16- 19%, 50- 65%, 370- 390 /100g, 100- 200mg/100g, 1500- 2200µg/100g, 3- 4.78 respectively. This is evident from the sweet spot indicated by overlaid contour plot as indicated in (Figure 16) consisting of the optimum combination of QPM, *Anchote*, carrot, and soybean that results in porridges with optimum nutrient composition. Considering both nutritional compositions and sensory attributes of the porridge sample investigated in the present study, the formulation with 55% QPM, 10% *Anchote*, 15% carrot, and 20% soybean was found to be the best combination to give porridge with optimum values of nutrient composition and overall sensory acceptability.

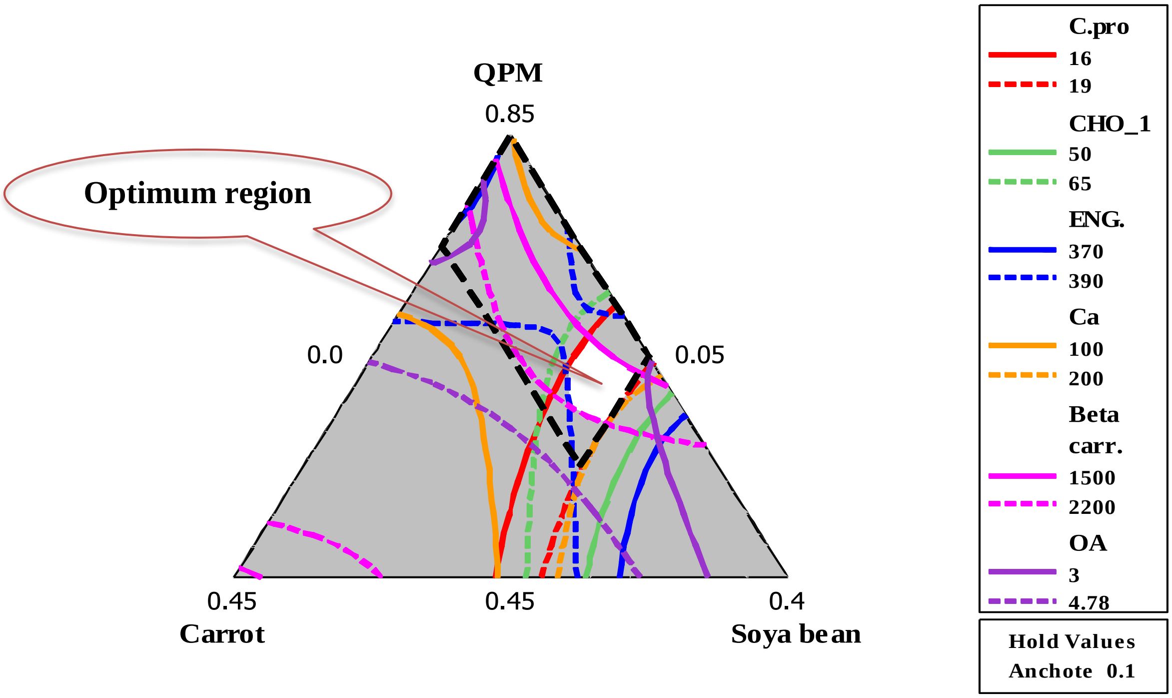

Figure 16: Overlaid contour plot of composite flours porridge overall acceptability for nutritional quality and sensory attribute of porridge holding *Anchote* constant at 10%

5. SUMMARY AND CONCLUSIONS

5.1. Summary

This study was undertaken to develop complementary food for under five children using local food ingredients that are commonly cultivated by the community in the study area. The local foods are mainly chosen based on their availability and affordability to tackle child malnutrition in the area. Results from this study showed that moisture, ash, protein, fat, fiber, carbohydrate, calorie, β-carotene, Calcium, Iron and Zinc, phytate, tannin content and overall sensory acceptability of the porridge made from different blends varied from 5-6.62%, 1.75-3.87%, 10.25 to 19.01%, 5.5-9.5%, 3.5-6%, 58.05 to 70.32%, 368.38 to 398.7kcal/100g, 1165 to 2215μg/100 g, 101.69 to 204.80mg/100g, 5 to 6.99mg/100g and 2.205 to 3.250 mg/100g, 80.58mg/100g, 8.92-14.66mg/100g and 3-4.78 respectively. However, the overall numerically optimized proportion of flours blends for better nutritional and sensorial quality is 55% QPM, 10% *Anchote* 15% carrot, and soybean 20%. Furthermore, pre-processing like soaking and roasting of soybean and germination of QPM resulted in decreased anti-nutritional factors, and improved the functional properties as well as sensory characteristics of porridges.

5.2. Conclusions

Thin porridge commonly made from locally available white maize or sorghum is a staple food for children in the study area. Such type of food is the main factor to cause malnutrition in children under the age of 5. To alleviate such limitations it is necessary to develop a complementary food made of different sources but dense in various nutrients. QPM, *Anchote*, Carrot and soybean composite flours were used to develop nutrient dense and sensorial acceptable complementary foods. As compared to individual flours of ingredients, the overall functional properties, nutrient and anti-nutrient contents and sensorial properties could be improved through finding proper ratio of flours blends.

Therefore, high nutrient density complementary food for children under the age of five can be formulated and produced from locally available sources through determining the right proportion of flour blends. As the local foods are easily affordable the complementary food developed from QPM (55%), *Anchote* (10%), carrot (15%) and soybean (20%) can be used to mitigate malnutrition problems since the formulation provides relatively better nutrient supply to meet the RDA normal growth and development of under-five age children in a sustainable manner. Intervention to mitigate malnutrition can be done through dietary diversification and food fortification. However, in the latter case under the context of developing countries it may not be easy to fortify and distribute nutrient dense complementary foods. Formulation and developed of complementary food in this study can be considered as one of the strategies to reduce the nutrient problem of food for target groups to diversify a diet though combining required food components from different nutrient sources.

6. RECOMMENDATIONS

This comprehensive study has laid the ground work to produce nutritionally improved and acceptable complementary foods from locally available food sources. The following are among the recommendations for future research areas to be undertaken in relation to complementary foods developed in the present study. Given that *Anchote* is one of the underutilized crops in Ethiopia, an effort should be made by relevant stakeholders to promote the crop to use in different value-added traditional and commercially processed foods. Proportion of flours determined in this study is not verified using human subjects for its efficiency to mitigate malnutrition of children. Therefore, further study need to be conducted to verify the result. Porridge was used as staple food for children in the community of the study area. But as an alternative food type, the best proportion in terms of nutrition and sensorial acceptability should be determined also for other food categories. Moreover, other anti-nutritional factors in addition to phytate and tannin such as trypsin inhibitors, lecithin's, alkaloids and saponins should also be considered in future studies.

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APPENDICES

Appendices A List of Table

Appendix Table 1: Analysis of variance for the functional properties and anti-nutritional contents

Source	BD	WAC	OAC	Viscosity	Phytate	Tannin
Linear	0.208	0.009	0.067	0.327	0.358	0.013
Quadratic	0.159	0.003	0.010	0.361	0.483	0.002
A*B	0.047	0.042	0.155	0.891	0.819	0.073
A*C	0.061	0.196	0.205	0.680	0.477	0.052
A*D	0.117	0.007	0.758	0.775	0.802	0.005
B*C	0.049	0.055	0.779	0.711	0.543	0.021
Norm.	0.352	0.248	0.138	0.106	0.195	0.812

A=Quality protein maize, B=Anchote, C= Carrot and D= Soybean Norm= Normality BD= bulk density WAC= water absorption capacity OAC= oil absorption capacity Visco= viscosity

Appendix Table 2: Analysis of variance for the proximate composition

Source	M.C	Ash	C.Protein	C.fat	C.Fiber	CHO	Energy
Linear	0.50	0.079	0.001	0.000	0.501	0.000	0.161
Quadratic	0.007	0.207	0.219	0.163	0.742	0.004	0.185
A*B	0.304	0.044	0.093	0.079	0.734	0.004	0.185
A*C	0.039	0.057	0.091	0.077	0.345	0.001	0.145
A*D	0.024	0.033	0.040	0.030	0.436	0.001	0.048
B*C	0.018	0.108	0.092	0.074	0.489	0.002	0.042
Norm.	0.212	0.331	0.207	0.367	0.543	0.083	0.299

A=Quality protein maize, B=*Anchote* , C= Carrot and D= Soybean Norm= Normality M.C= moisture content CHO= carbohydrate

Appendix Table 3: Analysis of variance for the mineral and beta carotene contents

Source	Calcium	Iron	Zinc	Beta carotene
Linear	0.004	0.000	0.248	0.033
Quadratic	0.017	0.003	0.022	0.180
A*B	0.005	0.022	0.853	0.057
A*C	0.068	0.857	0.315	0.049
A*D	0.009	0.080	0.282	0.090
B*C	0.062	0.153	0.065	0.122
Norm.	0.911	0.842	0.079	0.056

A=Quality protein maize, B=Anchote , C= Carrot and D= Soybean Norm= Normality

Appendix Table 4: Analysis of variance for sensory evaluation

Source	Color	Aroma	Taste	Mouth feel	Overall acceptability
Linear	0.000	0.000	0.001	0.014	0.001
Quadratic	0.001	0.001	0.002	0.023	0.002
A*B	0.812	0.137	0.942	0.896	0.457
A*C	0.024	0.805	0.044	0.329	0.012
A*D	0.808	0.028	0.795	0.576	0.544
B*C	0.049	0.882	0.161	0.751	0.048
Norm.	0.294	0.853	0.454	0.851	0.768

A=Quality protein maize, B=Anchote, C= Carrot and D= Soybean Norm= Normality

Appendix Table 5: Estimated regression coefficient of anti-nutritional and functional properties of individual and formulated complementary foods

No.	Term	Phytate		Tannin		BD		WAC		OAC		Viscosity	
		RC	SE	RC	SE	RC	SE	RC	SE	RC	SE	RC	SE
1	A	77.1	19.54	9.3	5.172	0.213	0.19	1.38	0.32	0.7	0.26	312	146.8
2	B	84.4	406.61	-229	107.6	-7.74	4.11	-15.5	6.6	-3.9	5.44	1307	3055
3	C	418.2	464.87	-326	123.07	-9.94	4.70	-12.6	7.6	-3.5	6.22	-348	3493
4	D	47.4	372.43	346.8	98.601	7.95	3.77	21.5	6.1	1.6	4.98	-1055	2798
5	A*B	135.3	573.7	308.2	151.88	13.36	5.80	22.1	9.3	11.9	7.67	-607	4311
6	A*C	-425.4	573.7	340.3	151.88	12.42	5.80	13.1	9.3	10.5	7.67	1840	4311
7	A*D	119.4	463.24	-458	122.64	-8.12	4.69	-26	7.5	-1.9	6.19	1025	3481
8	B*C	-757	1196.3	883.7	316.71	27.54	12.1	42.9	19.5	4.6	16	-3438	8989
	R^2(pre)	80.23%		86.61%		78.9%		90.6%		98.1%		93.4%	
	R^2(adj)	64.85%		76%		62.54%		83.4%		96.7%		88.2%	

A=Quality protein maize, B=Anchote, C= Carrot and D= Soybean BD= bulk density WAC= water absorption capacity OAC= oil absorption capacity RC= Regression coefficient; SE= standard error, R^2.coefficient

Appendix Table 6: Estimated regression coefficients of the proximate composition of individual and formulated complementary foods

No.	Term	M.C		Ash		C.Protein		C. Fat		C.Fiber		CHO		Energy	
		RC	SE	RC	SE	RC	SE	RC	SE	RC	SE	RC	SE	RC	SE
1	A	6.55	1.456	-5	2.82	8.2	1.828	4.28	0.8	3.7	2.05	79.7	3.69	391	17.84
2	B	-39.37	30.301	-126.5	58.7	-66.2	38.05	-30.4	16.64	-66	42.77	381.8	76.9	1000	371.22
3	C	-90.37	34.644	-137.6	67.11	-72.4	43.5	-33.2	19.02	-122.7	48.9	485.9	87.9	1383	424.42
4	D	71.93	27.755	140.6	53.76	130.6	34.85	62.61	15.24	108.8	39.18	-430	70.4	-289	340
5	A*B	46.65	42.754	193.5	82.82	101	53.68	46.54	23.48	81.8	60.35	-411	108.5	-837	523.78
6	A*C	103.12	42.754	180.7	82.82	101.6	53.68	46.84	23.48	142.2	60.35	-497.8	108.5	-1200	523.78
7	A*D	-93.24	34.522	-168.2	66.87	-104	43.35	-48.7	18.96	-128.4	48.73	459.7	87.6	1002	422.9
8	B*C	257.07	89.149	308.2	172.7	211	111.9	98.85	48.95	328.9	125.8	-1034	226	-2221	1092.2
	R^2(pre)	83.46%		72.34%		99.4%		99.54%		88.2%		98.8%		94.1%	
	R^2 (adj)	70.6%		70.2%		98.9%		99.1%		78.9%		97.9%		89.5%	

A=Quality protein maize, B=Anchote, C= Carrot and D= Soybean CHO= carbohydrate

RC= Regression coefficient; SE= standard error, R^2.coefficient

Appendix Table 7: Estimated regression coefficients of the mineral and beta carotene content of individual and formulated complementary foods

No.	Term	Calcium		Iron		Zinc		B-carotene	
		RC	SE	RC	SE	RC	SE	RC	SE
1	A	-219	77.2	4.23	1.095	2.61	0.57	1975	385.3
2	B	-5071	1606.7	11.29	22.788	-3.99	11.94	17216	8019.5
3	C	-3411	1837	-42.29	26.054	-17.68	13.65	29011	9168.8
4	D	5005	1471.7	36.05	20.873	15.74	10.93	-14175	7345.5
5	A*B	8424	2267	-5.96	32.153	3.31	16.84	-24713	11315.2
6	A*C	4702	2267	63.34	32.153	17.91	16.84	-25737	11315.2
7	A*D	-6059	1830.6	-40.51	25.962	-15.56	13.60	17372	9136.6
8	B*C	1009	4727.2	48.44	67.045	73.83	35.13	-40309	23594.2
	R^2(pre)	89.5%		91.17%		90.73%		97.90%	
	R^2 (adj)	81.3%		84.3%		83.5%		96.3%	

A= Quality protein maize, B=Anchote, C= Carrot and D= Soybean B= Beta carotene

RC= Regression coefficient; SE= standard error, R^2.coefficient

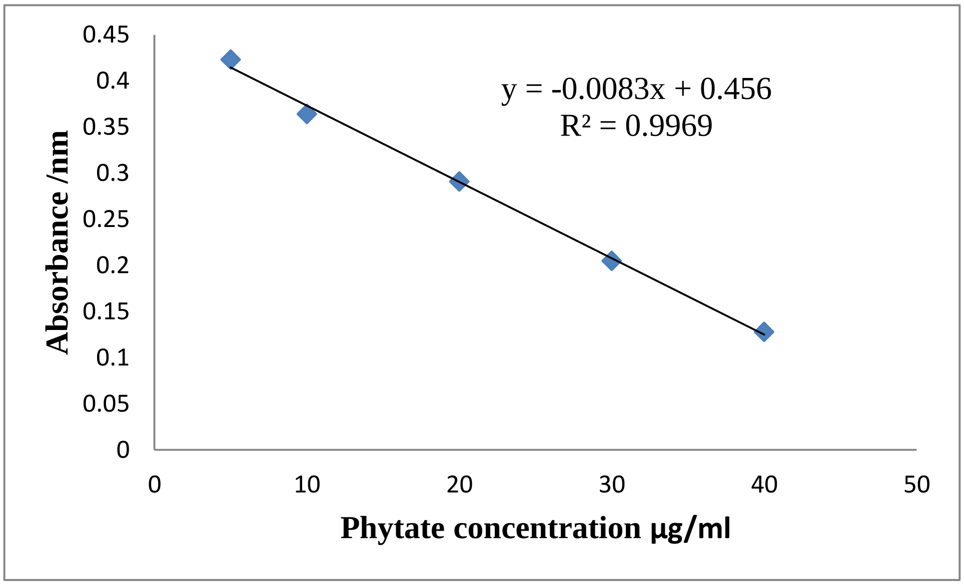
Appendix Table 8: Estimated regression coefficient for the sensory evaluation of complementary foods with various blending ratios

No.	Term	Color		Aroma		Taste		Mf		OA	
		RC	SE	RC	SE	RC	SE	RC	SE	RC	SE
1	A	2.4	1.3	2.86	1.005	3.7	1.04	4.13	1.01	4.6	1.3
2	B	10.3	26.9	-28.1	20.29	5.96	21.6	3.01	21.01	32.9	26.9
3	C	91.6	30.8	10.6	23.92	62.4	24.7	29.8	24.01	97.1	30.8
4	D	-7.1	24.7	45.48	19.17	3.7	19.79	11.1	19.24	-19.5	24.68
5	A*B	9.3	38	48.24	29.52	2.3	30.49	-4	29.63	-29.6	38.03
6	A*C	-102.9	38	-7.52	29.52	-71	30.49	-30.59	29.63	-119	38.03
7	A*D	7.7	30.7	-62.12	23.84	-6.6	24.62	-13.88	23.95	19.3	30.71
8	B*C	-180.7	79	9.42	61.56	-97.2	63.58	-20.24	61.79	-181	79.23
	R^2(pre)	90.2%		90.1%		91.3%		91.3%		89.18%	
	R^2 (adj)	82.6%		82.5%		84.6%		84.6%		80.77	

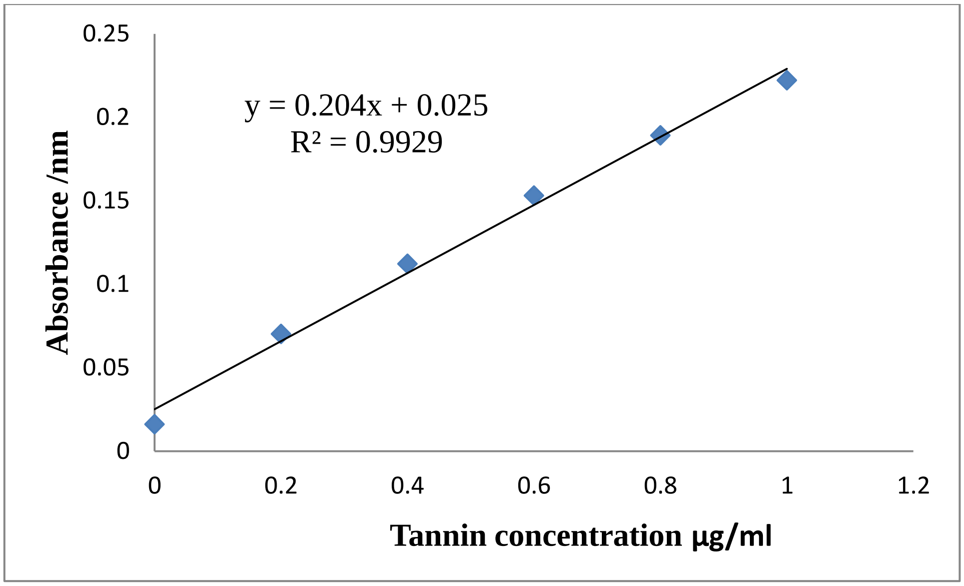
A=Quality protein maize, B=Anchote, C= Carrot and D= Soybean MF= mouth feel OA= overall acceptability

RC= Regression coefficient; SE= standard error, R^2.coefficient

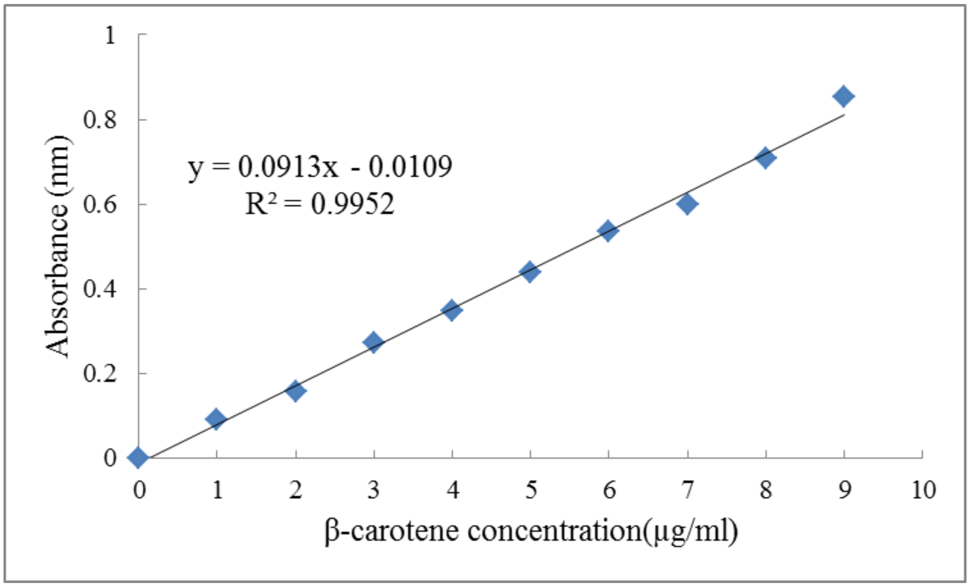
Appendix B: List of Figure



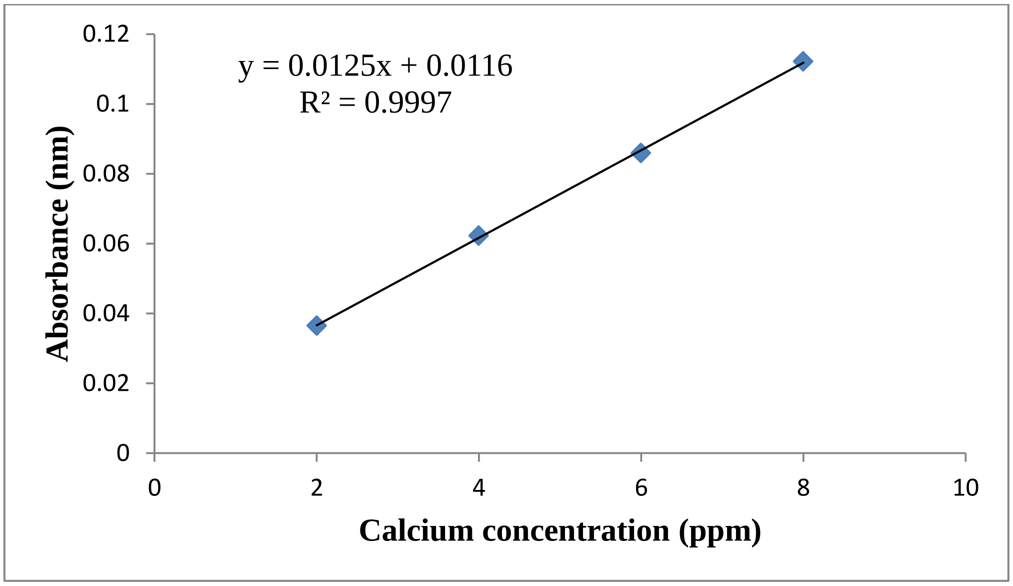
Appendix Figure 1: Calibration curve for phytate analysis



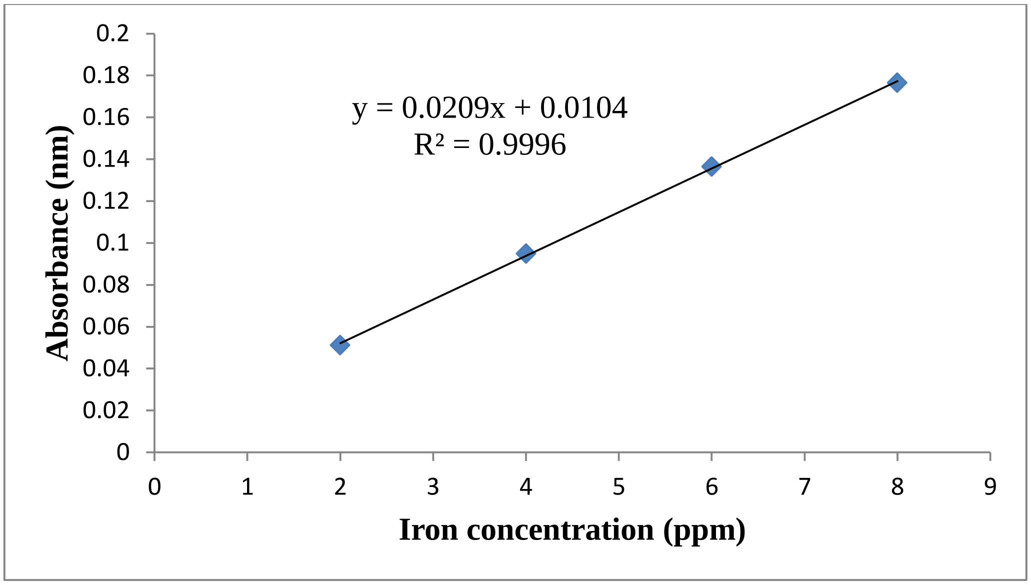
Appendix Figure 2: Calibration curve for tannin analysis



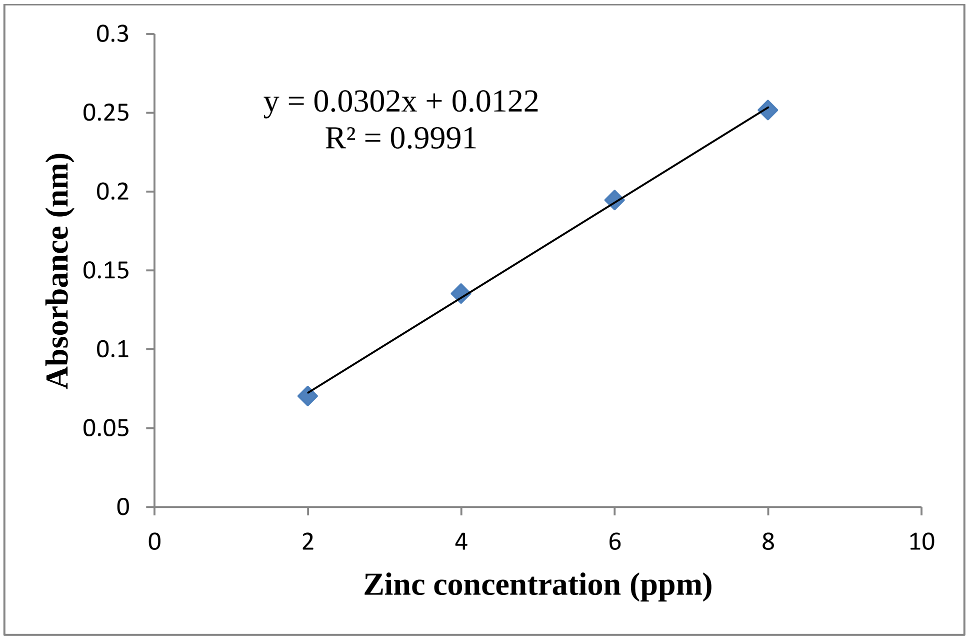
Appendix Figure 3: Calibration curve for beta carotene analysis



Appendix Figure 4: Calibration curve for Calcium analysis



Appendix Figure 5: Calibration curve for Iron analysis



Appendix Figure 6: Calibration curve for Zinc analysis

Appendices C: Sensory evaluators acceptability scorecard / sheet

Well come to this sensory evaluation panels of complementary food. You will be given complementary food samples. Write the sample code in the blank space. Kindly taste the samples and check the box for you are feeling about each of the sensory attributes. Please wash your hand and rinse your mouth between samples.

Thank you in advance for your cooperation.

Panelist Name____________________

Age_____________________

Sex______________________

Sample code________________

Sensory Perception:

1 = dislike extremely

2 = dislike slightly

3= neither like or dislike,

4= Like slightly and

5 = Like extremely,

Sample code	Color	Aroma	Taste	Mouth feel	Overall acceptability

Comments____

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