COMPLEMENTARY FOOD PRODUCT DEVELOPMENT FROM SORGHUM ENRICHED WITH CHICKPEA AND ORANGE-FLESHED SWEET POTATO: THE CASE OF DAWURO ZONE, SOUTH WESTERN ETHIOPIA

M.Sc. Thesis

By

Eleni Alemayehu

June, 2014

Jimma, Ethiopia

COMPLEMENTARY FOOD PRODUCT DEVELOPMENT FROM SORGHUM ENRICHED WITH CHICKPEA AND ORANGE-FLESHED SWEET POTATO: THE CASE OF DAWURO ZONE, SOUTH WESTERN ETHIOPIA

M.Sc. Thesis

Submitted to the 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 Post Harvest Management (Perishable)

By

Eleni Alemayehu

June, 2014

Jimma, Ethiopia

APPROVAL SHEET

Jimma University College of Agriculture and Veterinary Medicine Department of Post Harvest Management

Thesis Submission for External Defense Request Form (F-07)

Name of Student: Eleni Alemayehu Asfaw ID No. 00567/04

Program of study: MSc. In Post Harvest Management (Perishable)

Title: Complementary Food Product Development from Sorghum Enriched with Chickpea and Orange-Fleshed Sweet Potato: The Case of Dawuro Zone, South Western Ethiopia

I have completed my thesis research work as per the approved proposal and it has been evaluated and accepted by my advisers. Hence, I hereby kindly request the Department to allow me to present the findings of my work and submit the thesis.

Eleni Alemayehu ________________

Name and signature of student

We, the thesis advisers 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 is ready to be submitted. Hence, we recommend the thesis to be submitted.

Major Advisor: Kebede Abegaz (PhD.) ________________ ____________

Name Signature Date

Co-Advisor: Tilahun Abera (MSc) ________________ ____________

Name Signature Date

Internal Examiner (If Depends on the Verdict)

Name __________________ Signature ________________ Date

Decision/suggestion of Department Graduate Council (DGC) ____________

____

______________________________ ________________ ____________

Chairperson, DGC Signature Date

______________________________ ________________ ____________

Chairperson, CGS **Signature** **Date**

DEDICATION

This thesis manuscript is dedicated to my beloved parents and my husband.

STATEMENT OF THE AUTHOR

I, the undersigned, declare that this Thesis is my work and is not submitted to any institution elsewhere for the award of any academic degree, diploma or certificate and all sources of materials used for this Thesis have been duly acknowledged. This Thesis has been submitted in partial fulfillment of the requirements for M.Sc., degree at Jimma University, College of Agriculture and Veterinary Medicine and deposited at the University Library to be made available to borrowers under the rules of the library.

Brief quotations from this Thesis are allowable without special permission provided that an accurate acknowledgment of the source is made. Requests for permission for extended quotation from or reproduction of this manuscript in whole or in part may be granted by the Dean or Coordinator of the School of Graduate Studies or Head of the Department of Post Harvest Management when the proposed use of material is in the interest of scholarship. In all other cases, however, permission must be obtained from the author.

Name: Eleni Alemayehu

Place: Jimma University, Jimma

Date of submission: ___________

Signature_______________

BIOGRAPHICAL SKETCH

The author Eleni Alemayehu was born on November 1985 G.C in Assella town. She attended her elementary and junior education at Assella Silingo Lemlem School and Assella Junior and Secondary School from 1991 to 1998 G.C. Upon completing her junior school education, she attended her secondary and preparatory education in Assella high school from 1999 to 2002 G. C. Eleni Alemayehu started her university education at Mekelle University in September 2003 G.C. and graduated with Bachelor of Science degree B.Sc. in Dry Land Crop and Horticultural Science in horticulture stream in July 2007G.C.

After her graduation she was employed by Dawuro Zone, Loma Woreda in Rural Development and Agricultural Office as agronomist starting from October 1, 2007 G.C till she joined Jimma University College of Agriculture and Veterinary Medicine in September 2011 G.C to pursue her post graduate study in Post Harvest Management specializing in perishable crops.

ACKNOWLEDGMENT

Firstly, I am greatly thank the almighty GOD who gave me strength through all the times to complete the thesis work.

I would like to thank my advisors Dr. Kebede Abegaz and Mr. Tilahun Abera for their encouragements and guidance through the thesis work. My gratitude extends to Professor Tessema Astatikie and Mr. Sirawdink Fikireyesus for their kind support with the experimental data management and Dr.Yetinayet for his support to the lab analysis work timely.

I would like to express my heartfelt gratitude to Post Harvest Management Department and Jimma University College of Agriculture and Veterinary Medicine (JUCAVM) for giving me an opportunity to pursue my M.Sc. study in post harvest management through the PHMIL project funded by CIDA. I would like to acknowledge Ethiopian Health and Nutrition Research Institute, JUCAVM Animal Nutrition laboratory and Post Harvest Management laboratory for their all rounded facilitation and support to execute the experimental work timely.

My special appreciation goes to Melkasa Agricultural research center, Hawasa Agricultural Research Center and Debrezeit Agricultural Research Center for their giving the raw material for the thesis work. My deep acknowledges also goes to my friends and all Post harvest management staffs for encouraging and supporting during the thesis work. I would like to thank Dawuro zone Loma woreda rural development and Agricultural office and Health office for their facilitation and support during the survey data collection.

Finally, I would like to express my heartfelt acknowledgment to my family, Alemayehu Asfaw, Atsede Hailu and my husband Sisay Eshetu for their generous and unlimited support throughout my research work.

ABBREVIATIONS AND ACRONYMS

AAS	Atomic Absorption Spectrophotometer
AIs	Adequate Intakes
ANFs	Anti-nutritional Factors
AOAC	Association of Official Analytical Chemists
CF	Complementary Food
CSA	Central Statistics Authority
EHNRI	Ethiopian Health and Nutrition Research Institute
JUCAVM	Jimma University College of Agriculture and Veterinary Medicine
NPAAs	Non Protein Amino Acids
OFSP	Orange Fleshed Sweet Potato
Pas	Peasant Associations
PEM	Protein Energy Malnutrition
RAEs	Retinol Activity Equivalents
RDA	Recommended Dietary Allowance
SCN	Sub-committee on Nutrition
SNNPR	Southern Nations Nationalities and People's Region
UNAC	United Nation, Administrative Committee
USAID	United States Agency for International Development
VAD	Vitamin A Deficiency
VITAA	Vitamin A Partnership for Africa
WAC	Water Absorption Capacity

TABLE OF CONTENTS

Contents **page**

TABLE OF CONTENTS (*Continued*)

TABLE OF CONTENTS (*Continued*)

LIST OF TABLES

List of tables **page**

LIST OF FIGURES

List of figures **page**

LIST OF TABLES IN THE APPENDIX

ABSTRACT

One of the major problems associated with consumption of sorghum alone may result in micro- and macro-nutrient deficiencies that retard proper growth of Childs during complementary feeding period. The use of germinated grain composite flour can improve the micro- and macro-nutrient deficiencies. After survey on preparation of traditional complementary food (CF) in Dawuro, sorghum-based CF enriched with chickpea and orange-fleshed sweet potato (OFSP) in different proportion was developed; and nutritional and sensory quality of the CF was investigated using standard methods. Sixteen formulations of the composite flours were prepared using D-optimal constrained mixture design with the aid of Design-Expert with a range of sorghum 40-55%, chickpea 20-35% and OFSP 10-25%. The major response variables of nutritional composition (protein, fat, carbohydrate, energy, β-carotene, iron, zinc and calcium, anti-nutritional factors (phytate and tannin), functional proprieties (bulk density, water absorption capacity and sensory quality of the product were analyzed. The result showed a significant difference ($P<0.05$) in fat, protein, carbohydrate, energy, calcium, phytate, tannin, Water Absorption Capacity (WAC) and sensory attributes of the CF. The protein, fat and energy contents of the CF (porridge) prepared from blending ratio of chickpea at rate of 35% has increased significantly ($P<0.05$). Porridge prepared from 20- 25% proportion of OFSP showed significant ($P<0.05$) increase in β-carotene, ash and tannin content. Significant increase was noted in phytate content in the product prepared from composite flour from blending ratio of 40-55% sorghum. The overall optimum point of the composite flour were for protein ranged from 11.91-13.73%, energy 380.37-393.08 kcal, β-carotene 422.54-670.46 μg/100 g, iron 4.28-7.65 mg/100 g, calcium 65.18-71.54 mg/100 g. The overall acceptability was received hedonic rating of 3.52-4.68 on the bases of 5 scale within the range of sorghum (40-47.5%), chickpea (30-35%) and OFSP (20-25%). Sorghum, chickpea and OFSP flour induced significant improvement in the porridge nutritional quality and sensory attributes. The result revealed that sorghum, chickpea and OFSP crops have good potential for implementing vitamin A (β-carotene), protein and energy rich complementary food. Hence, using this optimum amount of formulation can improved the nutritional composition of the sorghum based CF. Strong attention should be given to perform further work on the promotion of sorghum, chickpea and OFSP products in Dawuro zone and other parts of Ethiopia.

Key words: Proximate, β-carotene, Composite flour, Complementary food, Porridge, Infant.

1. INTRODUCTION

Cereals are used as source of nutrition for one-third of the world's population, especially in developing and underdeveloped nations of Sub-Saharan Africa and South-east Asia (Shewry, 2007). Cereals have great nutritional importance in preparation of complementary food (CF) for children in developing countries like Ethiopia (Dicko *et al*., 2006). Among these cereals, sorghum is one of important crops ranking fifth after wheat, rice, maize and barley in terms of production (Smith and Frederiksen, 2000). Sorghum is a drought resistant crop of African origin being the second most important cereal food in Africa after maize (Taylor, 2004).

Sorghum is the main staple food which is used to feed infants in the form of thick and thin porridge either alone or with other crops (Dicko *et al*., 2006). There are different trends of utilizing sorghum in different parts of the world including Ethiopia. In many African countries, sorghum is milled into flour before fermentation and cooking for utilization as thin porridge in Africa and Asia, stiff porridge in West Africa, couscous in Africa, nasha and *kisra* in Sudan and ogi in Nigeria (Dicko *et al.,* 2005). It is the second preferred cereal after *teff* for preparing '*injera*', which is the staple food in Ethiopia and Eritrea (Ayana, 2001).

Utilization of sorghum for CF alone has been shown to be poor in protein content and amino acid profile (Achi, 2005). In addition to poor protein quality, sorghum grain contains significant amount of inherently found anti-nutritional factors (ANFs) that affect the bioavailability of nutrients. Some of these ANFs are tannins, phytic acid, polyphenols and trypsin inhibitors (Gilani *et al.*, 2005; Idris *et al.*, 2007). Tannins are reported to interact with proteins to form tannin–protein complexes resulting in inhibition of digestive enzymes (Mamary *et al*., 2002). Phytic acid is found to form complex with minerals which are highly insoluble at the physiological pH of human intestine, leading to lower mineral bioavailability (Walter *et al*., 2002; Amagloh *et al*., 2012). Therefore, this situation may be improved by the use of appropriate and sustainable intervention approaches, which include use of affordable bio-enrichment processing techniques such as fermentation and germination of cereals, legumes or oil seed mixtures at the household level and development of low cost, nutritious

CF from local available crops (cereals, legumes, roots and tubers) as a composite flour (Mosha *et al.*, 2000).

Composite flour of cereals and legumes like chickpea are important sources of energy and protein (Asha *et al*., 2005). The high lysine content of legumes improves the nutritional quality of cereals like sorghum by complementing their limiting amino acids (Ijarotimi and Ayantokun, 2006). Chickpea is the second most widely grown legume in the world (FAO, 2008) and it is one of the major pulses in Ethiopia and both in terms of its share of the total cultivated pulse area and consumption (Bekele and Hailemariam, 2007). This crop provides an important source of food and nutritional quality for the rural poor, especially those who cannot produce or cannot afford costly livestock products as source of essential proteins (Plahar and Annan, 1994; Bekele and Hailemariam, 2007).

The other composite flour ingredient was orange-fleshed sweet potato (OFSP) to improve the vitamin content of the composite flour. Orange-fleshed sweet potato is adaptable to diverse environments, high in yields and available year around (Mbwaga, 2007). It is the most promising crop sources of β-carotene which are believed to represent the least expensive (ACC/SCN 2000). Therefore, it could potentially make a major contribution to overcoming vitamin A deficiency in East and southern Africa (Tomlins *et al*., 2007). Orange-fleshed sweet potato is a good base in the preparation of baby CF, which can be enriched with protein-rich ingredients (Adenuga, 2010) like chickpea.

Since, many mothers in Africa used gruels made from sorghum as CF for their infants (Yusufu *et al.*, 2013); there is a need to innovate compatible ingredients from local crops for the preparation of the CF. Sorghum is limited in essential nutrients like lysine and do not contain pro-vitamin A (FAO, 1999). In Dawuro zone, the mothers are using red sorghum flour to prepare CF in the form of gruel and porridge for their young children. They believe that red sorghum have greater nutritional quality than the other sorghum varieties. Unfortunately, sorghum has low nutritional value due to limitation of essential amino acids, the presence of ANFs that forms complexes with macro- and micro-nutrients (Reed, 1995). The nutritional deficiency problems are common in this area that needs intervention to alleviate the problem through food-based strategy using locally available, nutrient-rich and affordable agricultural produces.

Therefore, cereal and legume proteins have a supplementary effect on each other, when appropriately blended (Nnam, 2001). Promoting consumption of locally available vitamin A-rich foods that can be grown in home gardens holds particular promise in many countries, due to its technical feasibility and cost-effectiveness. In this approach, OFSP can be a very suitable crop (Woolfe, 1992; Low *et al*., 1997). Hence, blending of this food ingredients through optimum amount can be assumed as a good option for improving the nutritional quality of sorghum based CF using simple technology like soaking, germination, and decortications.

In Ethiopia, particularly in rural communities, children are traditionally complementary fed on cereal (maize, teff, sorghum, barley) and root crops, (potato and sweet potato) based foods. Thos CFs are low in nutrient content and energy density. There are different strategies undertaken to reduce these problems. The present study has produced nutritionally improved porridge prepared from the composite flours of sorghum blended with chickpea and OFSP. The nutritional composition, anti-nutritional content and sensory acceptability of the blended CF was investigated allowing standard methods. In view of this, the present study was initiated with the following objectives.

Objective

General objective

- ➢ To assess the nutritional and sensory quality of sorghum based complementary food blending with chickpea and OFSP flour.

Specific objectives

- ✓ To assess the traditional preparation techniques of complementary food and its ingredients.

- ✓ To determine the nutritional composition and anti-nutritional factors of sorghum based porridge and its ingredients.
- ✓ To assess consumers' acceptance of the porridge as a complementary food prepared from sorghum, chickpea and OFSP composite flour
- ✓ To determine the functional property of composite flour and
- ✓ To investigate the optimum blending ratio of sorghum, chickpea and orange-fleshed sweet potato for preparation of nutritionally improved sorghum based complementary food in the form of porridge.

2. LITERATURE REVIEW

2.1. Production, Nutritional Composition and Consumption Trends of Sorghum, Chickpea and Orange-Flesh Sweet Potato

2.1.1. Sorghum

Sorghum bicolor (L.) Moench a tropical plant belonging to the family of *Poaceae* (Anglani, 1998). Total world annual sorghum production is about 57 million tons from cultivated area of 38 million ha (FAOSTAT, 2012). It is one of the main staple foods for the world's food-insecure people. It is a critically important food crop in sub-Saharan Africa on account of its drought tolerance. The increased use of sorghum as a food in this region could alleviate the problem of chronic under nourishment, as sorghum is much better suited to cultivation in the semi-arid tropics than non-indigenous cereals such as wheat or maize (Dewar, 2003).

Sorghum is one of the important cereal crop cultivated in Ethiopia for different traditional food preparation. In 2012, the total sorghum production in Ethiopia is about 3,604,262 tons from cultivated area of 1,711,485 ha (FAOSTAT, 2012; CSA, 2013). It is a staple food crop on which the lives of millions of poor Ethiopians (Asfaw, 2007).

2.1.1.1. Nutritional composition and uses of sorghum flour for complementary food formulation

The nutritional composition of sorghum grains were highly starch and lower in proteins, fat and fiber content (Table 1) (Beta *et al*., 1995; Dicko *et al*., 2005). Sorghum is also rich in phosphorus, potassium, iron and zinc (Glew *et al*., 1997; Anglani, 1998). Sorghum protein is generally low in the essential amino acids such as lysine and tryptophan but it was rich in sulphur containing amino acids (tryptophan) (Ijarotimi *et al*., 2006).

Sorghum grains serve as a major ingredient for many unique indigenous foods and beverages. It is consumed in different forms at different parts. Traditionally, sorghum based foods are broadly grouped in to four (FAO and ICRISAT, 1996). These are flat breads, porridges, boiled products and snacks (special foods). The most common traditional food made from sorghum are thin porridge (gruel); thick porridge (fermented and unfermented) flat unleavened fermented bread and unfermented bread (Rooney and Waniska 2000; Taylor and Belton, 2002; Taylor *et al*., 2008). Fermented sorghum porridge is an important staple food item for people of the West African sub-region. It is also important complementary foods for infants due to its high calorific value and presence of some mineral elements (Adebayo-Oyetoro *et al*., 2012).

2.1.2. Chickpea

Chickpea was utilized as raw green, tender stage or as mature dry seeds in different forms like flour, snack food and supplement in CFs (Alajaji and Eldawy, 2006). It is a good source of protein which is highly digestible (18 to 31%) (Sharma *et al*., 2013) and protein quality is better than other legumes such as pigeon pea, black gram and green gram (Kaur and Singh, 2005; Wood and Grusak, 2007). In contrast it has some limitations due to the presence of certain ANFs such as tannins, phytates and trypsin inhibitors has been also reported by some authors earlier (Siddhuraju *et al*., 2000; Sharma, *et al*., 2013).

Chickpea (*Cicer arietinum* L.) is one of the oldest cultivated legumes, as it is believed to have originated in the Middle East approximately 7450 years ago (Maiti and Wesche- Ebeling, 2001). Chickpea is a major food legume in Southern Europe, North Africa, India and Middle East countries (Viveros *et al*., 2001; Iqbal *et al*., 2006). In 2012 the world total chickpea production was 11,625,545 tons from cultivated area of 12,344,291 ha (FAOSTAT, 2012). It is widely grown and most widely consumed legumes in the world due to relatively high protein content and wide adaptability as a food grain (FAO, 2008). It is a valuable, ancient leguminous plant which grows well in different soils and climates (Rincon *et al*., 1998).

Chickpea is one of the major legumes grown in Ethiopia and the total annual chickpea production is about 409,733.1 tons from cultivated area of 239,512 ha (CSA, 2013). The crop provides an important source of food and nutritional security for the rural households, especially those who cannot produce or cannot afford costly livestock products as source of essential proteins. The consumption of chickpea is also increasing among the urban population mainly because of the growing recognition of its health benefits and affordable source of proteins (Bekele and Hailemariam, 2007).

2.1.2.1. Nutritional composition and uses of chickpea flour for complementary food formulation

Chickpea is a good source of energy, protein, minerals, vitamins and is an excellent source of both soluble and insoluble fiber, complex carbohydrates, vitamins, folate, and minerals, especially calcium, phosphorous, iron, zinc and magnesium (Kaur and Singh, 2005; Wood and Grusak, 2007; Wang *et al*., 2010). Whole chickpea contains 54-71% carbohydrate and 3.0 % minerals where the food energy is 334-437 kcal/100 g (Wood and Grusak, 2007) (Table 1). They are also a source of high-quality protein and have been known as "a poor man's meat" (Isabel and Garmen, 2003). Chickpea is low in fat and sodium (Wood and Grusak, 2007; Menale *et al.,* 2009).

It has been used for the preparation of various traditional foods, such as an ingredient in bakery products, infant food formulations and meat products (Ravi and Suvendu, 2004). In Ethiopia, chickpea can be consumed in the form of de-hulled (split seed), and soaked and roasted (snacks) and boiled seeds ('nifro') (Dejene, 2010). Dried legume seeds generally promote slow and moderate postprandial blood glucose increase (Isabel and Garmen, 2003).

2.1.3. Orange-fleshed sweet potato

Sweet potato (*Ipomoea batatas*) is dicotyledonous plant that belongs to the family *Convolvulaceae*. Sweet potato ranks third of the world root and tuber group production after potato and cassava (FAOSTAT, 2008). It is adaptable to diverse environments, has high yields, performs well in marginal soils, is available all year round and is cheap to grow (Maleki, 2001). Current world production has been estimated over 103 million tons per annum (FAOSTAT, 2012). It is a very important crop that is widely consumed in sub-Saharan Africa (Woolfe, 1992). A sweet potato production in Sub-Saharan Africa is 17.9 million tons per annum representing only 17.45% of the world production, and it is almost exclusively used for human consumption (FAOSTAT, 2012).

Sweet potato is among well known and established crops in Southern, Eastern and South western parts of Ethiopia. It is produced annually on over 41 thousand hrs of land with total production over 1,185,050 tones and average productivity of 28.4 tons per hectares (CSA, 2013). Ethiopia is one of the largest sweet potatoes producing country in east Africa and the Southern Nations Nationalities and Peoples' Region (SNNPR) is the major sweet potato producing region in the country. According to the CSA agricultural sample survey data (2013), it is the 2^{nd} to potato in area of production and productivity (Ermias *et al*., 2013).

In sub- Saharan Africa the majority of sweet potato that is consumed is white fleshed and has low levels of pro-vitamin A (β-carotene) (Ameny and Wilson, 1997). Orange-fleshed sweet potato variety is naturally bio-fortified crop and it has great potential for use in food based intervention program to address vitamin A deficiency. Currently the bio-fortified OFSP varieties have shown to be capable of reducing vitamin A deficiency in studies on children in sub-Saharan Africa (Jaarsveld *et al*., 2005; Low *et al*., 2007). The OFSP is less labor intensive than most other crops and can be planted over a broad range of seasons without considerable yield loss (Woolf, 1992).

2.1.3.1. Nutritional composition and consumption trend of Orange-Fleshed Sweet Potato

Sweet potatoes are rich in starch, dietary fiber, β-carotene, vitamin C and B_6 (Table 1), which is depends upon varieties. Particularly, orange-fleshed sweet potato varieties are potentially excellent raw materials because of their high β-carotene content (Woolfe, 1992). Orange-fleshed sweet potato is the most promising plant sources of β-carotene; β-carotene from sweet potato is substantially better (in terms of bioavailability) than leafy vegetables or other vegetables. The Prominent characteristics of OFSP are nutritional and sensory versatility in terms of its micronutrient contents (Esther and Ignitiatus., 2010).

Sweet potatoes in Sub-Saharan Africa are limited to boiling, roasting and drying. In developing countries, dried products (chips, starch and flour) were identified as the most promising products from orange-fleshed sweet potato compared to the many options available. Its flour has been used as substitute to other flours, such as sorghum and wheat. In

Sub-Saharan Africa products developed from dried OFSP is include porridge, bread and chapatti (Bechoff, 2010). Consumption of boiled OFSP improved vitamin A status of children and can significantly complement vitamin A supplementation initiatives to minimize vitamin A deficiency (VAD) in children (Van Jaarsveld *et al*., 2005).

Table 1 Nutritional Composition of Sorghum, Chickpea and OFSP

Nutritional composition	Sorghum	Chickpea	OFSP
Protein (%)	7 -15[a,c]	16.7 - 30.57[d,f]	4.62[h,i]
Fat (%)	1.5 - 7.6[a,c]	2.9 - 7.42 [d,f]	0.71-0.91[h,i]
Fiber (%)	1.71-3.34[a,b,c]	3.7-13 [d,f]	4.91 [h,i]
Moisture (%)	8-12[a,]		7.36 [h,i]
Ash (%)	1-4[a,b]	2.04-4.2[d,f]	5.36 [h,i]
CHO (%)	65-80[a,]	50.64-64.9[d,f]	
Energy (kcal/100 g)	365.84 - 385.88[a,g]	334 – 437[d,f]	70-460 [h,i]
B-carotene (µg/100g)	-	-	348 -7128 [h,i]
Na (mg/100 g)	-	1-121[e]	-
K (mg/100 g)	220[a,]	230-1272[e]	324[i]
Ca (mg/100 g)	3.75 – 21[a,]	176[e]	101-103 [i]
Mg (mg/100 g)	75.02,140[a,]	1.78-5.16[e]	19.6 [i]
P (mg/100 g)	100.60 – 368[a,]	226[e]	57.7 [i]
Mn (mg/100 g)	-	2.11[e]	0.38 [i]
Zn (mg/100 g)	0.75 - 2.5[a,]	2.2 - 20 [e]	0.24 - 3.68 [i]
Cu (mg/100 g)	0.61-1.8[a,]	0.31-11.6 [e]	0.12 [i]
Fe (mg/100 g)	0.9-20[a,b]	3 - 12 [e]	0.62-0.84 [i]

Source: [e]Petterson *et al*., 1997; [d]El-Adawy, 2002; [a] Dicko *et al*., 2006; [i]Linghton, 2007; [f]Wood and Grusak, 2007; [c]Shimelis *et al.,* 2009; Esther and Ignitiatus, 2010; [g]Makinde and Ladipo, 2012; [h]Gebremedhin *et al*., 2013; [b]Ratnavathi and Patil, 2013

2.2. Major Anti-nutritional Factors in Sorghum, Chickpea and Orange-Fleshed Sweet Potato

Plants often accumulate potent chemical defense compounds called anti-nutritional factors (ANFs). Some of these ANFs are lactins, protease inhibitors, non-protein amino acids (NPAAs), alkaloids, cyanogenic glycosides, pyrimidine glycosides, saponins, tannins, isoflavones, oligosaccharides, phytic acid or phytates (Rosenthal and Berenbaum, 1991; Bardocz *et al.,* 1996).

Anti-nutritional factors are chemical substances in food that do not offer nourishment to the body. They interfere with nutrients absorption by chelating or different types of complexo metric reactions with vital nutrients obtained from dietary sources. Trypsin inhibitors and tannins inhibit the digestibility of protein. Phytic acid reduces the bioavailability of some essential minerals like iron and zinc (Vidal *et al*., 1994; Urbano *et al*., 1995; Rehman and Shah, 2001). Sorghum and chickpea contain several ANFs like R-galactosides, trypsin inhibitors, amylase inhibitors; tannins and phytic acid while ANFs in OFSP includes tannins, polyphenols and trypsin inhibitors (Esther and Ignitiatus, 2010). The effect of these ANFs in the body depends on the type and the concentration in which it is present in the food material (Alonso *et al*., 1998).

2.2.1. Phytic acid (phytate)

Phytic acid (myoinositol hexaphosphate) present in most plant materials at high concentration in cereal, legume and nuts. Phytate found at low concentrations in roots, tubers and vegetables as phytate salt and it is the main phosphorus store in mature seeds (Reddy *et al*., 1989; Sandberg, 2002). Cereals contain approximately 1-2% phytic acid, and it can even rich 3-6%. Whole grain of several sorghum varieties contain phytate phosphorus can be in the range of 170 to 380 mg per 100 g; and over 85% of the total phosphorus in the whole grain bound as phytate phosphorus (Makokha *et al*., 2002; Lorenz *et al*., 2007). The distribution of phytate phosphorus in sorghum grain also showed that a greater percentage of phytic acid in the germ than in bran and least in the endosperm (FAO, 1995). In particular, wholegrain cereals and legumes have a high content of phytate (Sandberg, 2002). In legumes a considerable proportion of phosphorus (60 to 80%) is formed as phytic acid or complexed with protein (Emami and Tabil, 2002). Ravindran *et al*. (1994) found that the phytate phosphorus in chickpea was 51.2% of the total phosphorus content. The total phytic acid content in chickpea has been reported to vary from 0.3 to 1.8% (Ravindran *et al*., 1994; Burbano *et al*., 1995; Rincon *et al*., 1998). Phytic acid content will vary with genotype, climate, type of soil and year (Muzquiz and Wood, 2007).

Phytic acid binds some essential elements such as iron, calcium, zinc and phosphorus to form insoluble salts called phytate, which are not absorbed by the body and thereby reducing the bioavailability of these elements (Hussain *et al*., 2011). This occurs because of the formation of insoluble complexes with these elements (Gilani *et al*., 2005). It associates with proteins and chelates metal ions (Alemu, 2009) to form protein-mineral-phytate complexes which are highly insoluble at the physiological pH of human intestine (Khertapaul and Sharme, 1997; Sandberg and Andlid, 2002). In contrast to the anti-nutritional properties, dietary phytate has also been suggested to have beneficial effects, such as protection against colon cancer, arteriosclerosis and coronary heart diseases (Sandberg and Andlid, 2002; Ogunkoya *et al*., 2006).

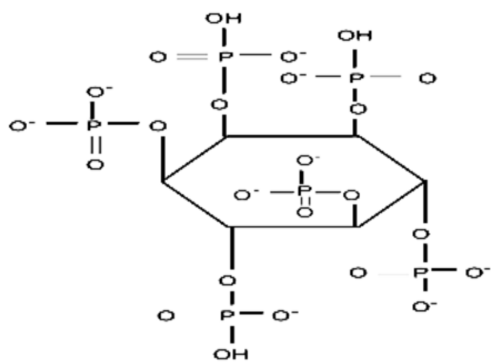


Figure 1 Chemical structure of Phytic Acid

2.2.2. Tannin

Tannins are naturally occurring water-soluble polyphenolic compounds with the ability to complex and precipitate proteins in aqueous solutions (Jansman *et al*., 1994). Their molecular weight ranges from 300 and 3000 Daltons (Mingshu *et al*., 2006). Tannins are predominantly located in the pericarp and/or testa, particularly of pigmented cultivars of legumes and millets (Deshpande *et al*., 1982). The tannin content of chickpea has been reported in different literature approximately 0.12–0.72 g/100 g of total tannin, which (<0.1% in desi and <0.04% in kabuli) is condensed tannin (Petterson *et al*., 1997; Salgado *et al*., 2001). Chickpea contains low tannin contents, with concentrations (both total and condensed) much lower than faba bean (*Vicia faba*), pigeon pea (*Cajanus cajan*) and lentil (*Lens culinaris*) (Muzquiz and Wood, 2007). Garcia-Lopez *et al*. (1990) found that tannins from chickpea caused no significant reduction in iron absorption, in contrast to tannins from tea, coffee and wine.

Sorghum tannins which are condensed polymeric polyphenols are capable of binding non-haem iron (Fe) and form complexes with proteins (Emmanbux and Taylor, 2003; Melaku *et al.,* 2005), to inhibit enzymes of the digestive system (Ogunkoya *et al.,* 2006). ANFs in sweet potato include tannins, polyphenols and trypsin inhibitors. Esther and Ignitiatus (2010) reported that the tannin content of OFSP ranges from 0.20 - 0.25% in two varieties. The presence of tannin in fresh foods and processed products causes browning or other pigmentation problems and acts as anti nutritional factor by provoking astringent feel in the mouth, thereby rendering the food unacceptable (Onimawo and Akubor, 2005).

Tannins may form a less digestible complex with proteins, carbohydrates and lipids leading to a reduction in digestibility of these nutrients and reduced energy value of a diet containing tannins and it also interfere with iron absorption (Hagerm and Carson, 1998; Adeparusi, 2001; Abera, 2003; Onwuka, 2005). The mechanism of dietary effects of tannins may be understood by their ability to form complex with proteins (Kumar and Singh, 1984). Tannins were divided into two groups based on their ability to form fractions by hydrolysis (with acid, alkali, hot water or enzymatic hydrolysis) as hydrolysable tannins (including gallotannins and ellagitannins) and condensed tannins (proanthocyanidins) (Muzquiz and Wood, 2007).

Condensed tannins

The condensed tannins, mainly polymerized products of flavan-3-ol (catechin) and flavan-3,4-diol or mixture of these, are resistant to hydrolysis. The condensed tannins which are also referred as flavolans or procyanidins, are the main polyphenols present in commonly consumed food products while the hydrolysable forms are present only in small amounts (Salunkhe *et al*., 1990).

Condensed tannins are all oligomeric and polymeric proanthocyanidins formed by linkage of C-4 of one flavanol moiety with C-8 or C-6 of the next monomeric flavanol. These linkages are more difficult to be hydrolyzed (Clifford and Scalbert, 2000; Khanbabaee and Ree, 2001). It is commonly found in the seed coats of many plants and in the foliage of several legumes and grass cultivars (Waghorn *et al*., 1990; Terrill *et al.*, 1992). The condensed tannins have a more profound digestibility reducing effect than hydrolysable tannins (Kumar, 1992). Condensed tannins are present in the pigmented testa of sorghum grains (Asante, 1995).

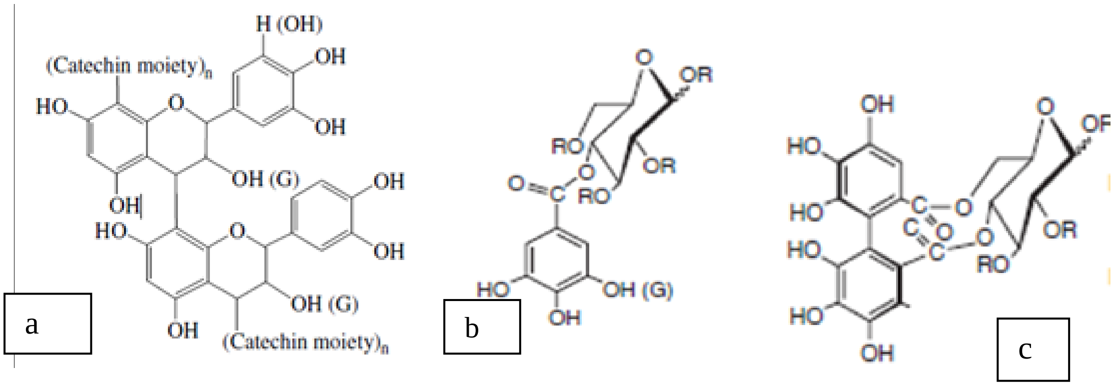


Figure 2 Chemical structure of (a) condensed tannins and hydrolysable tannin ((b), gallotannin and (c) ellagitannins)

Hydrolysable tannin

Hydrolysable tannins split into sugars and phenolic carboxylic acids in acid and alkaline conditions (Amlan, 2012) and are further classified according to the products of hydrolysis into gallo tannins (gallic acid and glucose) and ellagic tannins (ellagic acid and glucose) (Nalle, 2009). Gallotannins are those tannins in which galloyl units or their meta-despotic derivatives are bound to diverse polyol, catechin or triterpenoid units. Ellagitanins are those tannins in which at least two galloyl units are C—C coupled to each other and do not contain a glycosidically linked flavanol unit (Weinges and Plieninger, 1999; Zhang *et al*., 2001). The hydrolysable tannins are not considered to have more anti-nutritional effects, but are responsible (with some other polyphenolic compounds) for the colour of seed coats (Muzquiz and Wood, 2007). Hydrolysable tannins can be broken down to their hydrolysis upon heating with weak acids or enzymatically (Khanbabaee, and Ree, 2001).

2.3.Effect of Processing on Nutrient Composition and Anti-Nutritional Factors

The anti-nutritional factors can be eliminated or reduced by cooking or with other simple technologies (Vidal *et al*., 1994; Urbano *et al*., 1995) although processing will improve the nutritive utilization of protein. There are the traditional processing techniques include: (i) non-heat processing methods such as germination, de-hulling or fermentation and (ii) heat processing, such as cooking at atmospheric pressure, autoclaving and roasting. 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, saponins and phytic acids 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 haves been reported by many researchers to alleviate the effect of ANFs and to improve the nutritional value of cereals and legume seeds (Idris *et al*., 2007; Mohamed *et al*., 2010; Mohiedeen *et al*., 2010; Osman *et al*., 2010; Sokrab *et al*., 2012). Mainly, 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 (Oboh *et al*., 2000; Ramakrishna *et al*., 2006).

2.3.1. Germination

Germination is one of the most common techniques used to reduce most of the ANFs (Hussain *et al*., 2011). It is a simple biochemical enrichment tool to enhance the palatability, which incidentally may result in increasing the digestibility and nutritive value through its indispensable food ingredients. The level of ANFs trypsin inhibitory activity, phytates, tannins and total polyphenols reduced considerably during germination. Germination was more effective in reducing trypsin inhibitor activity, tannins, polyphenols and phytic acid than the various cooking treatments (Ramakrishna *et al*., 2006). Germination also improves the consistency, mouth feel and taste of the product (Egli 2001; Helland *et al*., 2002). Several studies have shown that germination improves the nutritive values and sensory attribute of cereals and legumes. It has also been found to decrease the levels of ANFs present in cereals and maximizes the levels of some utilizable nutrients (Mohamed *et al*., 2007) reducing the bulk density.

The effects of germination and cooking treatments on the nutritional composition and ANFs of chickpeas were studied by El-Adawy (2002). The author found that germination was more effective in reducing phytic acid, stachyose and raffinose in chickpea than cooking. Rao and

Deosthale (1982) found germination to decrease tannin content of chickpeas by a further 10% after soaking overnight.

2.3.2. Decortications

Decortication is a common processing method of producing de-hulled seed. De-hulling removes the seed coat, which contains different types of ANFs, such as tannins ~90% (Rao and Deosthale, 1982). Therefore, the resulting de-hulls improves the bioavailability of protein, carbohydrates and vitamins. Decortications' can considerably reduce the level of phytate and phenolic compounds in cereals like sorghum because these ANFs are mainly concentrated in the bran and the aleuronic layer of the grain (Beta *et al*., 1999; Frossard *et al*., 2000).

2.3.3. Soaking

Soaking also reduces certain ANFs, which leach into the soaking medium, such as oligosaccharides, protease inhibitors and some tannin (Saxena *et al*., 2003). The amount of leaching will vary depending on the soaking medium (water, salt solution or bicarbonate solution) and soaking time. Rao and Deosthale (1982) found that the tannin content of chickpeas had reduced by almost 50% after soaking overnight in water.

2.4. Functional Properties

The functional properties of flours play an important role in manufacturing of products (Akubor *et al.,* 2013). Kinsella (1976) have been defined the functional properties are refer to those physical and chemical properties; that influence the behavior of proteins in food systems during processing, storage, cooking and consumption. The functional properties such as water and oil absorption capacities, particle size distribution, bulk density and gelatin of flour are important to determine; either the flour would be useful in development of food, those functional properties affect processing applications, formulations, food quality, storage thereby altering the texture, and sensory qualities of food product beyond satisfying the basic nutritional requirements (Mahajan and Dua, 2002; Wu *et al.*, 2009). The properties of flour such as Water Absorption Capacity (WAC), bulk density and viscosity predict the functional properties of developed products (Guria, 2006).

2.4.1. 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. Bulk density is an indication of the porosity of a product which influences package design and could be used in determining the type of packaging material required, material handling and application in wet processing in the food industry (Kinsella, 1987). According to Peleg and Bagley (1983), 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. Bulk density is also important in infant feeding where less bulk is desirable. The low bulk density of flour would an advantage in the use of the flour for preparation of complementary foods (Akubor *et al.,* 2013).

2.4.2. Water Absorption Capacity

Water absorption of flour is dependent mainly on the amount and nature of the hydrophilic constituents and to some extent on pH and nature of the protein (Gordon, 1993). Water absorption characteristic represents ability of the product to associate with water under conditions when water is limiting such as dough's and pastes (Akubor *et al.,* 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 *et al.*, 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).

2.4.3. Viscosity

Viscosity of a CF is the most important determinant of energy density. The viscosity of gruels (CF) in turn depends in large part on the degree of starch gelatinization and proteins which are predominant nutrients in cereals, root and tubers and oil seeds (Chavan and Kadam, 1989). 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). Infant needs a gradual transition from fluid to solid foods which allow the infant to develop feeding skills. Early complementary feeding, the infant will reject very viscous foods by spitting them out. During complementary feeding period, inadequate intake of energy and protein occurs due to traditionally prepared CFs, have high viscosity but low energy density and limit the infant's ability to eat enough and satisfy the need of its body growth (Walker, 1990).

2.5. Complementary Food

Complementary foods (CF) are any food other than breast milk given to a breastfeeding child and the process is called complementary feeding practice (WHO, 1998). Complementary food is mostly prepared in the form of thin porridges or gruels (Brunken *et al*., 2006). When breast milk alone is no longer sufficient, complementary feeding can meet the additional nutritional requirements of the infants. The complementary feeding begins at 6 months when transition from exclusive breastfeeding to semi-solid foods begins and continues up to the age of 24 months (Daelmans and Saadeh, 2003; Anigo *et al*., 2009). During the first four to six months of life, all nutrients required by an infant can be provided by breast milk and so there's no dietary need for the introduction of solid food (Trussel, 2003). By the age of 6 months most infant need additional foods, to complement the breast milk and make certain nutrient to provide enough energy and nutrients for normal growth. This goal is only achieved when these foods are prepared and feed to the infants under hygienic conditions and given in adequate proportions (Akaninwor and Okechukwu, 2004).

In most developing countries, CF is derived mainly from local staples such as cereals and tubers, with less animal proteins as supplements. However, since animal proteins are expensive, attempts have been made to identify alternative sources of protein, especially from plants (Metwalli *et al*., 2011). In countries where cereals are a staple, mothers usually use cereal crops in children's homemade CF. Cereals are deficient in lysine and tryptophan but have sufficient sulphur containing amino acids which are limited in legumes whereas legumes are rich in lysine. The effects of the complementing cereals with legumes are highly beneficial, since protein quality of the product is also improved (Amankwah *et al*., 2009).

Nutrition plays an important role in life even before birth and an infant's nutrition during the first two years. This is for the growth, development and maturation of body tissues which occur rapidly during the first two years (Whitney and Rolfes, 1999). According to Wardlaw and Insel (2000), an infant typically increase in length by 50% in the first year. Such rapid growth requires both nourishment and sleep in abundance. They also need concentrated source of nutrient and energy to support their tremendous growth and development. When an infant is inadequately feed there is the risk of stunted growth and a range of biochemical changes that can impair development to the extent of permanently damaging the infant health, education and economical performance as adult later on.

The quality of CF used to feed a baby has been found to be very crucial to mental development of baby. The most rapid growth of the brain occurs from 5 months before birth to 10 months after birth. At the end of the first year of life, the brain, first organ to attain full development has achieved 70% of its adult weight (Wardlaw and Insel, 2000). Poorly nourished babies have fewer and smaller brain cells than those well nourished (Barker, 2001). Most authors have indicated that early and severe malnutrition is an important factor in deficiencies in late mental development apart from social and hereditary influences (Wardlaw and Insel, 2000).

In a situation of resource poor conditions like rural Ethiopia, development of CFs from nutrient-rich and locally available crops is the best for long term food-based strategy to control nutritional deficiency problems in infants. However, the newly developed CF formulations must be acceptable and not associated with any adverse health effects among target end user or infants and young children. Various findings on the use of composite flour for infant CF preparation were reviewed to support the present research project. It has been noted that, in selecting the components to be used in composite flour blends meant for preparation of infant foods, the materials should preferably be readily available, culturally acceptable and provide increased nutritional potential to solve observed nutritional deficiencies. The two ingredients (sorghum and chickpea) used in this research for developing CF are among common foods known by the local people in the survey area. The white fleshed sweet potato is staple food in this area but not the OFSP. Consequently, the success rate of acceptability of the product by the users is promising.

One of the major limitations that might be raised here is, the ingredients are not wholesome to be used independently for preparation of the CF. One ingredient might be good in its macronutrient content while another ingredient might be poor in macronutrient content but a good source of micronutrients such as vitamin A and iron. Therefore, formulation of different flour from different crops is a choice for compensating the lack of nutrients in each of the ingredients. However, information on optimum blending ratio of each ingredient in the CF preparation with enhanced nutritional value and sensory acceptability is scanty. Thus, this research is aimed to generate baseline information and to make recommendation on the best formulation of nutritionally enriched porridge with desirable sensory attributes from the blend of sorghum, chickpea and OFP. Moreover, the best formulation of flour to yield porridge with low anti-nutritional contents will also be reported. As a result, baseline information on the nutritional and anti-nutritional contents of this newly developed porridge will be available with recipe for other users in Dawuro zone**.**

2.6. Recommended Dietary Allowance for infant

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 and gender group. 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 individual about 97.5 percent (Food and Nutrition Board, 2005).

Table 2 Recommended dietary allowance for infants and children

Life stage	Protein (g/d)	Fat (g/d)	Carbohydrate (g/d)	Fiber (g/d)	Vitamin A (µg/d)**	Ca (mg/d)	Zn (mg/d)	Fe (mg/d)
Infants								
0-6 Months	9.1*	31*	60*	ND	400*	210*	2*	0.27*
7-12 Months	**11**$^{+}$	30*	95*	ND	500*	270*	**3**	**11**
Children								
1-3 years	**13**	ND	**130**	19*	**300**	500	**3**	**7**
4-8 years	**19**	ND	130	25*	**400**	800	**5**	**10**

Source: Food and Nutrition Board, Institute of Medicine, National Academies (2002/2005)

**As retinol activity equivalents (RAEs). 1 RAE = 1 µg retinol, 12 µg β-carotene

Recommended Dietary Allowances (RDAs) in **bold type** and Adequate Intakes (AIs) in ordinary type followed by an asterisk (*).

3. MATERIALS AND METHODS

3.1. Description of the Study Area

The study encompasses two parts: field survey and laboratory based chemical analysis. The field survey was conducted in Loma woreda of Dawro Zone at four peasant association (PAs). Dawuro Zone is located in the Southwestern part of Ethiopia between Latitude 6^o59 and 7^o34 N and Longitude 36^o68 and 37^o52 E and the altitude ranged from 501 to 3000 meters above sea level. With mean monthly temperature ranges from 15.1 to 27.5 ^oC and annual rainfall ranged from 1201-1800mm. The agricultural practices was crop-livestock mixed farming and keep combination of livestock species integrated with a wide range of cereals, pulses, root and tubers and cash crops (coffee and cotton) grown for household consumption and marketing (CSA, 2006; PCC, 2008).

Loma woreda is geographically located 475 km southwest of Addis Ababa and 178 km from Jimma town about $6^0$52'37.84"N latitude and 37^0 21' 46.14"E longitude at an altitude 1170 meters above sea level (EMA, 2012).

The laboratory-based experimental work was conducted at Jimma University, College of Agriculture and Veterinary Medicine (JUCAVM) and Ethiopian Health and Nutrition Research Institute (EHNRI). JUCAVM is geographically located at south western part of Ethiopia at 346 km from Addis Abeba, at about $7^0$33' N latitude and 36^0 57’ E longitudes at an altitude of 1710 meters above sea level. The two laboratories room temperature while the experiment was performed in the rage of 23-25 ^oC and 22-25 ^oC for post harvest management and EHNRI respectively.

3.2. Field Survey

3.2.1. Sample size determination and sampling procedure

Loma woreda was selected using purposive sampling technique based on the available information as there is high food shortage in the woreda (Loma woreda health office annual report). Consequently, nutritional deficiencies are common community problems in the study area that needs intervention to mitigate the problem through food-based approach using locally available, nutrient-rich and affordable farm produces. Four peasant associations (PAs) were selected using purposive sampling technique from the Loma woreda based on the pre-test survey. These PAs are produce sorghum and sweet potatoes; and consumed in sorghum grain as a CF. The third level of sampling was selection of household respondents using purposive sampling method. The selected households were those who have child at 6-24 months old.

Before the selection of sample households at each selected PAs sample size were established. This was done primarily by recording total household in respective PAs. The total sample size of the survey was determined after getting the total number of household in each PAs. Total numbers of sample size were determined using probability proportional to sample size-sampling technique using the formula developed by (Cochran, 1977).

$$n_o = \frac{Z^2\, x\, (p)(q)}{d^2} \longrightarrow n = \frac{n_o}{(1+\frac{n_{o-1}}{N})}$$

Where:

n_{o} = the desired sample size Cochran’s (1977), when population is greater than 10,000

n = Finite population correction factors (Cochran’s formula, 1977), when population is less than10000

Z = is 95% confidence level i.e.1.96

P = 0.15 (Proportion of population to be include in sample i.e. 15%)

q = 1-P i.e. (0.85)

N = Total number of population

d = is degree of accuracy desired (0.05)

Table 3 Number of household (HH) in the peasant associations (PAs) of Loma district

PAs Name	Total HH	Respondent
Zima Waruma	270	39
Deneba Bola	282	41
Lala Anbe	354	51
Subo Tulema	524	76
	1430	207

Total of 207 sample households (respondents) were selected for survey from 1430 household's residing in four PAs. Finally, total sample size were distributed into the sample PAs proportional to the total size of households in order to select the sample households proportional to the size of household head living in each sampled PAs.

Then the survey data was collected using semi-structured questionnaire; which were first developed in English. The English versions were translated to Amharic. Pre-test survey questionnaire was done on 18 mothers from the two districts. The survey was conducted to get the information on local complementary food preparation, processing, composition and feeding practices.

3.3. Raw Materials

The experimental materials used for laboratory analysis were 1kg local sorghum variety was collected from Dawro Zone Loma Woreda local market, 12kg of sorghum (*Bicolor* L. Moench), 7 kg of chickpea (*Cicer arietinum* L.) and 100 kg of orange-fleshed sweet potato (*Ipomoea batatas*) **"***Tula***"** variety and they were collected from Melkassa Agricultural Research Center, Debre Zeit Agricultural Research Center and Hawassa Agricultural Research Center respectively.

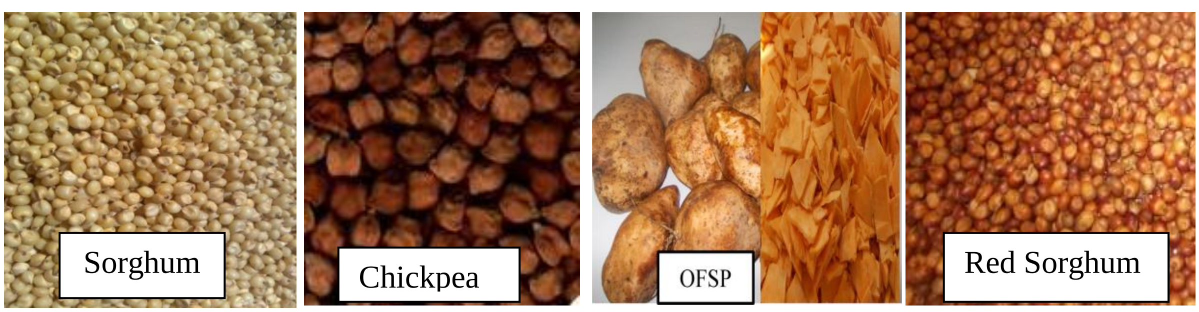


Figure 3 Raw materials used in the experiment

3.3.1. Sample Preparation

3.3.1.1. Preparation of sorghum flour

Preparation of sorghum flour was done according to the method developed by (Almeida-Dominguez *et al*., 1993) with some modification (using germination cabinet and improves the germination time from 36 to 24 hr). Twelve kg of sorghum grains were cleaned, sorted, small, broken and immature grain, dust, sand, stones, and other foreign materials were removed. The cleaned sorghum was washed with distilled water and soaked in a volume of water three times the weight of seed (1:3, w/v) for 22 hrs at room temperature. The steeping water was drained off. The soaked sorghum grains were washed using distilled water and germinated for 24 hrs at 25 ^{o}C with the relative humidity of 85 % in the germination cabinet. After 24 hrs, the germinated sorghum was sun dried until the moisture content reached 12 % and milled by disk miller (Kaelkolb, D-6072 Dreich, West Germany), packed in airtight polythene plastic bags and stored at room temperature in dry place. Local sorghum grains were used as a control without any treatment. The local sorghum grains were cleaned, dried, milled, sieved and packed in airtight polythene bags and stored at room temperature until it is needed for chemical analysis.

3.3.1.2. Preparation of chickpea flour

Preparation of chickpea flour was done according to the method developed by Esmat *et al.,* (2010). Defective grains (with holes), stones and other debris were removed. The clean chickpea was soaked overnight in a volume of water 3 times the weight of seed (1:3 W/V) at room temperature. The chickpea was drained off, de-hulled manually, sun dried until the moisture content attained 12%, milled by disk miller (Kaelkolb, D-6072 Dreich, West Germany), sieved and packed in airtight polythene bag, and stored at room temperature until it is needed for chemical analysis.

3.3.1.3. Preparation of orange fleshed sweet potato flour

Preparation of OFSP flour was done according to Woolfe (1992) method with some modification. The OFSP roots were manually washed, peeled, and sliced in to small size (2-3 cm) and sun dried by covering with black cloths until sufficiently dried. The dried OFSP flakes was milled (Kaelkolb, D-6072 Dreich, West Germany), sieved, packed in airtight polythene bags and stored at room temperature in a dark place to prevent the β-carotene from thermal light reaction. For the whole raw materials processing and analysis see Figure 3 below.

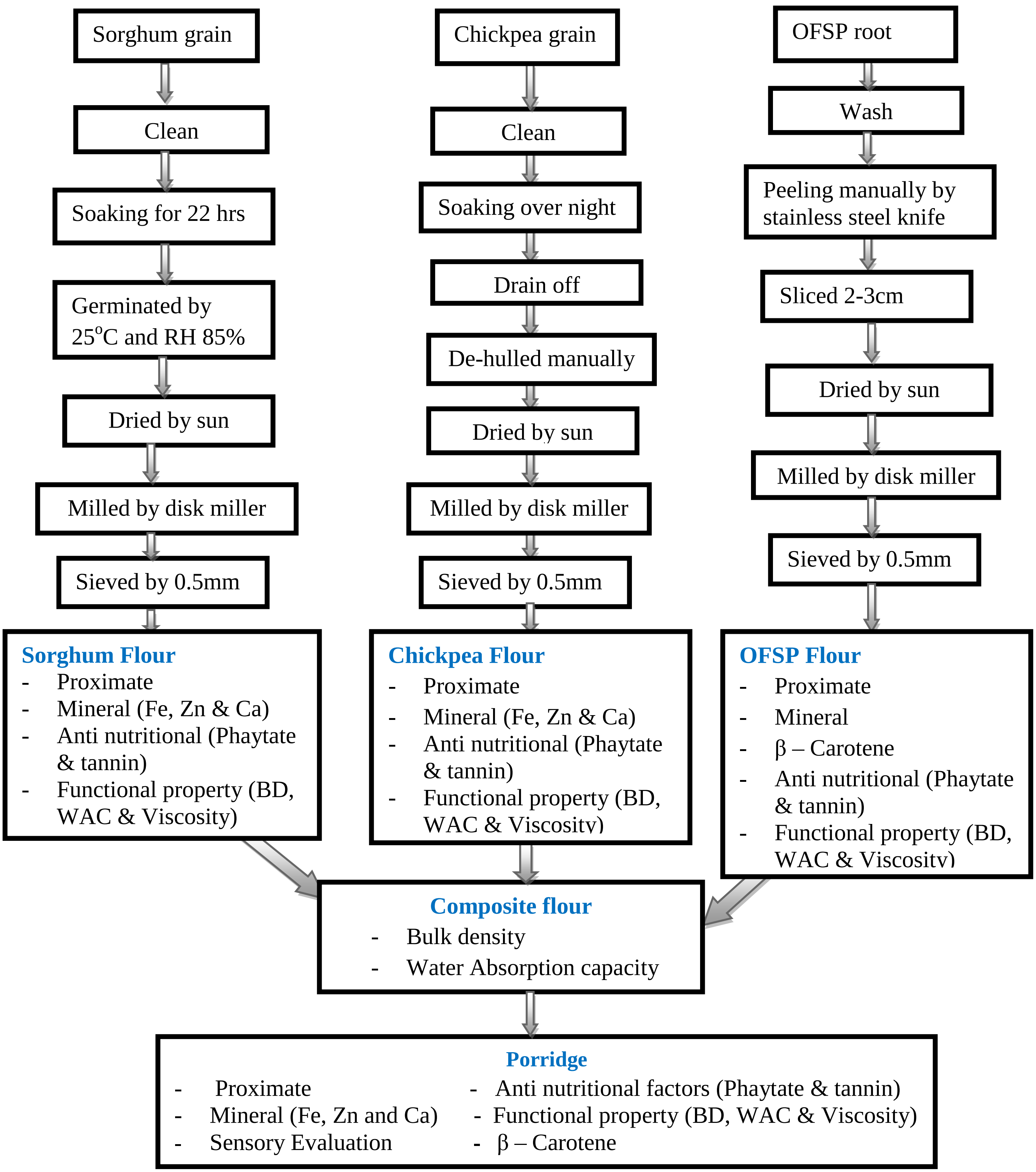


Figure 4 Flow diagram of experimental framework and preparation of flour samples

3.3.2. Experimental design and formulation of composite flour

3.3.2.1. Experimental design

This study was carried out to find the appropriate ratio of sorghum, chickpea and orange-fleshed sweet potato in composite flours for complementary foods. D-optimal mixture design with a total formulation of 16 (Table 4), which was obtained by inserting a range of sorghum 40-55%, chickpea 20-35% and OFSP 10-25%, was used to set up the experiment (Table 4). The range of thus ingredient was determined based on different literatures and household trends in the study area (Mahgoub, 1999; Esmat *et al*., 2010; Aziah *et al*., 2012; Adebayo-Oyetoro *et al*., 2012; Hefnawy *et al*., 2012). Flour of the three basic ingredients was formulated by blending three of them using computer generating Design-Expert®, version 8, Stat-Ease software. The simplex design plot for the 3-components of mixture formulations (sorghum, chickpea and orange-fleshed sweet potato) was presented in Figure 4 shows the experimental point and the experimental region.

Table 4 Lower and upper limits of compost flours in mixture design

Ingredients	Lower limit	Upper limit
Sorghum	40	55
Chickpea	20	35
OFSP	10	25

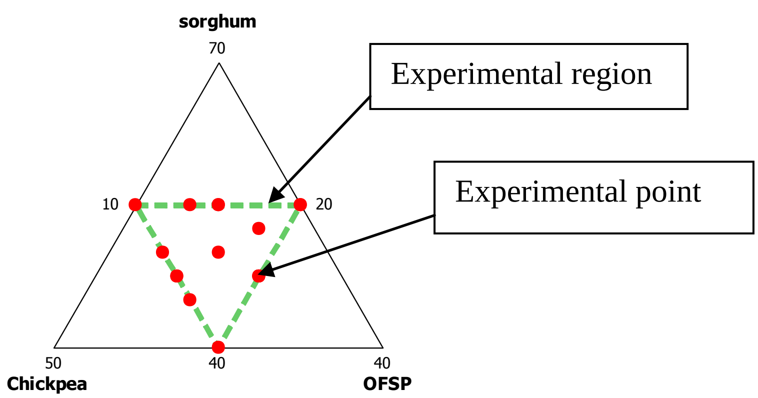


Figure 5 Simplex design plot for the 3-component mixture formulations

3.3.2.2. Blending of sorghum based complementary food

Food formulation for infant and young children is undertaken using Cameron and Hofvander, (1983) methods. In this experiment, a multi-mix infant formula was including three basic ingredients:

i. Staple as the main ingredient (sorghum)
ii. Protein source from a (chickpea)
iii. Vitamin source from (orange-fleshed sweet potato)

In order to formulate CF, the primary criteria are to select ingredients that are rich in providing protein, energy and vitamins (vitamin A) requirements of young children.

Table 5 Blending of CF from sorghum, chickpea and orange-fleshed sweet potato flour.

Run order	Ingredients		
	Germinated Sorghum	Chickpea	OFSP
1	40.0	35.0	25.0
2	47.5	27.5	25.0
3	47.5	27.5	25.0
4	47.5	27.5	25.0
5	55.0	20.0	25.0
6	55.0	20.0	25.0
7	52.5	25.0	22.5
8	45.0	35.0	20.0
9	50.0	30.0	20.0
10	47.5	35.0	17.5
11	47.5	35.0	17.5
12	55.0	27.5	17.5
13	55.0	27.5	17.5
14	50.0	35.0	15.0
15	55.0	30.0	15.0
16	55.0	35.0	10.0

3.3.2.3. Porridge preparation

Porridges were prepared according to Onabanjo *et al*. (2009) from each sixteen composite flour sample. Three hundred grams (300) g of each composite flour mixed with 300 mL of distilled water in small plastic bowl. The rest 200 mL of distilled water was boiled in the pan and after it boiled, the slurry was mixed with the boiled water then heated for 15 min at 90±3^{o}C with continuous stirring to avoid coagulation and sticking on the pan. After 15 min the pan with porridge removed from the stove. All analysis and sensory evaluation data were collected using the different analysis procedures.

3.4. Laboratory Analysis

Different response variables were measured and data were collected at different level of the experiment. Data were collected on proximate composition, β-carotene content, mineral content, anti-nutritional factors, functional properties and sensory evaluation of porridge developed from different level of sorghum, chickpea and OFSP composite flour blends. Experiental data collection and analysis were conducted at Post-harvest Management laboratory, animal nutrition laboratory at JUCAVM and Ethiopian Health and Nutrition Research Institute (EHNRI). Sensory evaluation at community level was conducted at Deneba Bola peasant associations Loma Woreda, Dawuro Zone.

3.4.1. Proximate composition

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

3.4.1.1. 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, 2005) method 925.10. The petri dish was dried at 130 ± 3^{o}C for 1 hr and placed in desiccator and weighed after cooling. About 2 g of porridge flour were weighed by analytical balance and put on dry dish. Dry dish and its contents put in the oven (LEICESTER LE67 5FT, England) maintained at 130°C ± 3°C for 1 hr. The sample containing dish was transferred to a desiccator and weighed soon after reaching room temperature. Then, the moisture content was estimated by the formula:-

$$\boldsymbol{Moisture}\ (\%) = \frac{(\boldsymbol{M_{intial}} - \boldsymbol{M_{dried}})}{\boldsymbol{M_{intial}}} \boldsymbol{x100}\% \ldots\ldots \text{Eq. 1}$$

3.4.1.2. Determination of total ash (%)

Ash content of the composite flour and individual crop flour samples were determined by (AOAC, 2005) method 923.03. The crucibles were cleaned and dried at 120°C and ignited at 550°C in furnace (Model SX-5-12, China) for 30 min. The crucibles were removed from the furnace and were placed in desiccators to cool down to room temperature. The mass of crucibles were measure by analytical balance and the reading was recorded as (M_1). About 3 g of the composite flour and individual crop flour samples were weighed in to crucibles (M_2). The sample was dried at 120°C for 1 hr in drying oven (LEICESTER LE67 5FT, England). The sample was placed in 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 (M_3):-

$$Total\ ash(\%) = \left(\frac{M_3 - M_1}{M_2 - M_1}\right) x100 \ldots\ldots \text{Eq. 2}$$

3.4.1.3. Determination of crude protein (%)

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

Calculation =Total nitrogen by percent

$$Total\ nitrogen = \frac{(T-B)x\ N\ x14.007\ x\ 100}{w} \text{...Eq. 3}$$

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

3.4.1.4. Determination of crude fat (%)

Crude fat of composite flour and individual ingredient flour was determined by Soxhlet extraction according to (AOAC, 2005) method, 2003.06. About 2 g of sample was weighed and put into a thimble. The thimble and its contents was placed in to a 50 mL beaker and dried in an oven (Memmert 854, West Germen) for 2 hrs at 102±2^{o}C. The thimble contents were transferred in to extraction unit. The sample contained in the thimble was extracted with the solvent diethyl ether in a Soxhlet extraction apparatus (Foss Tecator, Sweden) for 6 hrs. After the extraction completed, the extraction thimble was dried in the oven (Memmert 854 schwabach, West Germen) for 30 mins at 102^{o}C ± 2^{o}C to remove moisture. Then it was removed from the oven and cooled in a desiccator. The cup and its contents were weighed. The crude fat was determined by the following formula:-

$$Crude\ fat(\%) = \frac{W_2-W_1}{Weight\ of\ sample}\ x\ 100\% \text{...Eq. 4}$$

Where: W_1= Weight of extraction flask before extraction

W_2 = Weight of extraction flask after extraction

3.4.1.5. Determination of crude fiber (%)

The crude fiber was determined by the non-enzymatic gravimetric method of (AOAC, 2000) method, 920.168. About 1.5 g food sample was place into 600mL beaker. A 200 mL of 1.25% H_2SO_4 solution and boiling chips was added to each beaker and allowed to boil for 30 min by rotating and stirring sometimes. 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 crucibles with their contents was dried for 2 hr at 130^{o}C in the oven (Memmert 854 schwabach, West Germen) and cooled in desiccators and weighed (M_1). Then again they were ashed for 30 min at 550^{o}C in furnace (Stuart 2416, UK) and were cooled in desiccators. Finally the mass of each crucible was weighed (M_2) to subtract ash from fiber. The crude fiber was calculated from the equation:-

$$Crude\ fiber\ \% = \frac{M_1 - M_2}{weight\ of\ sample}\ x\ 100 \quad \text{......Eq. 5}$$

Where:

M_1 = mass of crucible and wet residue

M_2 = mass of crucible and ash residue

3.4.1.6. Determination of utilizable carbohydrates (%)

The utilizable carbohydrate content of the composite flour and individual ingredient flour samples was determined by difference method using the following mathematical expression.

$$Utilizable\ CHO(\%) = 100 - (\%M.c + \%\ C.fat + \%Ash + \%C.f + \%C.P) \quad \text{......Eq. 6}$$

Where: CHO= Carbohydrate, C.fat= Crude fat, C.f=Crude fiber,
C.P= Crude protein M.C= Moisture content

3.4.1.7. Gross energy (kcal)

Gross energy of composite flour sample was calculated according to the method developed by Osborne and Voogt (1978).The energy content of each individual ingredient and composite flour samples were calculated as follow:-

$$Caloric\ value\ (kcal) = (protein\% \times 4) + (CHO\%\ \times 4) +\ (fat\ \% \times 9) \ldots\ldots\ldots\ldots \text{Eq. 7}$$

3.4.2. Determination of β-Carotene

The beta carotene was determined by using spectrophotometer method described by (Rodriguez, and Kimura, 2004). Homogenous 7 g food samples were weighed and blend in a mechanical blender/ mortar and pestle with enough acetone. Filter in to 100mL volumetric flask washed the mortar, funnel and residue with small amount of acetone, receive the washing in flask containing the extract. Before repeating, the extraction was filtered until the residue is devoid of any color and washings are colorless. Add about 25 mL of PE in a separator funnel and was added the acetone extract in to the separator funnel. Add small amount of distilled water and shake well. Let the two phase separate and discard the lower aqueous-acetone phase. Wash repeatedly with distilled water to remove residual acetone. Collect the petroleum ether phase and dried with sodium sulphate (add sodium sulphate until some crystal become loose). The PE phase was transferred to drying flask and evaporate to dryness on a rotary evaporator (Stuart 3022, UK). The residues were dissolved in 1 mL of Petroleum Ether and introduce the solution in to a chromatographic column. Elute with Petroleum Ether and collect the β-Carotene in a flask, β-Carotene goes through a column as a yellow pigment. Measured the volume of β-carotene elutes using measuring cylinder. The absorbance was read at 440 nm by UV-vis spectrophotometer (CE1021, England)**.**

$$Amount\ \left(\frac{\mu g}{g}\right) = \left(\frac{A \times V(mL) \times 10^4}{A_{1cm}^{1\%} \times W}\right) \ldots\ldots\ldots\ldots \text{Eq.8}$$

Where:

A = Absorbance

$A_{1cm}^{1\%}$ = Absorption coefficient of carotenoids in solvent used PE is 2592

V (mL) =Volume of the solution that gives an absorbance of A at a specified wavelength

W = weight of sample in gram

3.4.3. Determination of anti-nutritional factors

3.4.3.1. Phytate determination

Phytate determination was done as per the method described by Vaintraub and Lapteva (1988). About 0.0573 g of composite flour sample was weighed and extracted with 10 mL of 0.2N HCl for 1 hr at an ambient temperature then centrifuged at 3000 rpm/30 mins The clear supernatant was collected and 3 mL of sample solution was mixed with 2 mL of Wade reagent (0.03 % solution of $FeCl_3.6H_2O$ containing 0.3% sulfosalicylic acid in water) followed by homogenization and centrifugation of the solution (3000 rpm for 10 min). The absorbance was read at 500 nm measured using UV-Vis spectrophotometer (CE1021, England). The phytate concentration was calculated from the difference between the absorbance of the blank (3 mL of 0.2N HCl +2 mL of wade reagent). The amount of phytic acid was calculated using phytic acid standard curve.

$$phytic\ acid\ in\ \frac{\mu g}{g} = \frac{Absorbance - Intercept}{Slope \times Density \times weight\ of\ sample} \quad \text{....................................Eq. 9}$$

3.4.3.2. 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 1% HCl in methanol for 24 hrs at room temperature with mechanical shaking (Edmund Buhler, USA) then centrifuged at 3000 rpm for 5 min. One milliliter 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 UV-Vis Spectrophotometer (CE1021, England). A stock catechin solution was used as the standard (20 mg catechin dissolved in 100 mL 1% HCl in methanol) and value of tannin was expressed in mg of 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.

$$Tannin\ in \frac{mg}{g} = \frac{Absorbance - Intercept}{Slope \times Density \times Weight\ of\ sample} \quad \text{.........Eq. 10}$$

3.4.4. Mineral analyses

The mineral analyses were determined by Flame Atomic Absorption Spectrophotometer (AAS) (Auto sampler AA 6800, Japan) method as per the (AOAC, 2005) method, 985.35. One g of composite flour and individual ingredient samples were ashed and weighed. The white ash was treated with 5 mL of 6N HCl and dried on the hot plate. Added 15 mL of 3N HCl and heat the crucible on the hot plate until the solution just boiled. The solution was cooled and filtered through a filter paper in to 50 mL graduated flask then make up with distilled water. Then the solution was used to determine Ca, Zn and Fe. Standard stock solution of iron, zinc and calcium was made by appropriate dilution. The sample and standard was atomized by using reducing air-acetylene for Ca and oxidizing air-acetylene for zinc and iron as a source of energy for atomization (AACC, 2000). 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 10 mL. 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 2.5 mL. For Calcium content determination, absorbance was measured at 422.7 nm after addition of 2.5 mL of $LaCl_3$ was added to sample solution and standard to suppress interferences. Calcium content was then estimated from standard solution 0, 2, 4, 6, 8 and 10 mL prepared from $CaCO_3$.

3.4.5. Functional properties

3.4.5.1. Bulk densities of the flour

Bulk density was determined by the method of (Adeleke and Odedeji, 2010). Fifty gram flour sample was placed into a 100mL measuring cylinder. The cylinder was tapped several times on a laboratory bench to a content volume. The volume of sample is recorded. Bulk density was calculated from the values obtained as follows:

$$Bulk\ density\ \left({}^{g}/_{cm^3}\right) = \frac{weight\ of\ sample}{volume\ of\ sample\ after\ tapping} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots....\text{Eq. 11}$$

3.4.5.2. Water absorption capacity

The WAC was determined using the method developed by Beuchat (1977). One gram sample was mixed with 10 mL of distilled water for 30 seconds in a mix (set on fast speed). The samples were allowed to stand at room temperature for 30 min, centrifuged at 2000 rpm (Centrifuge model 800-1) for 30 min and the volume of the supernatant was measured in a 10mL graduated cylinder.

$$Water\ absorption = 10\ mL - final\ reading\ from\ the\ cylinder \ldots\ldots\ldots\ldots\ldots\ldots\ldots.\text{Eq. 12}$$

3.4.5.3. Viscosity determination

The viscosity of complementary porridge was determined by back extrusion method using texture analyzer (TA-XT plus Goldalming, surrey GU71y1, UK). One hundred gram of each composite flour sample was mixed with 100 mL of distilled water in small plastic bowl. The rest 70 mL of distilled water were boiled in pan. The slurry was mixed with the boiled water in to pan then heated for 15 min at 90±3 ^{o}C with continuous stirring to avoid coagulation and sticking in the pan. After 15 min, it was removed from the stove and transferred to back extrusion container (12.66 mm diameter and 34.94 mm length) and the samples were allowed to cool 40^{o}C on the water bath boiler (WB-8B). The texture analyzer was set on the pre-test and post-test speed 5 mm/sec, test speed 1 mm/sec and distance was 30 mm. The prob (part no T.A 10) was used.

3.4.6. Sensory evaluation

Porridge was prepared with from each sixteen composite flours. Porridge samples were coded with three digits randomly and were allowed for sensory evaluation. Sensory attributes measured were color, aroma, taste, mouth-feel and overall acceptability using a five point hedonic scale**,** where 1= dislike extremely, 2 = dislike moderately, 3 = neither like nor dislike, 4 = like moderately and 5 = like extremely (Muhimbula *et al*., 2011). A total 50 untrained females panelists were participates in this study. The use of mothers instead of the target recipient infant was necessary because of their ability to evaluate objectively the sensory characteristics of the formulations to the interest of their children. After tasting each coded sample they rinsed their mouths before moving on to the next sample and use expectorate for spitting. Then the score of all judges for each sample were summed up and divided by the number of panelists to find the mean value.

3.4.7. Data analysis

The survey data was analyzed using SPSS version 20 statistical software. For the experimental data MINITAB version 16 software packages was used for data analysis, creation of contour plot and overlaid plot of the results. These formulations were obtained based on a constrained D-optimal mixture design. The statistical significance of the terms in the regression equations was examined by analysis of variance (ANOVA) for each response and the significance test level was sated at $P < 0.05$.

4. RESULT AND DISCUSSION

This study was undertaken both field and laboratory conditions. The field survey data were collected from respondents using semi-structured questionnaires, while the laboratory analysis was conducted using samples mentioned in chapter three. The results of this study are separately presented in figures and tables with the respective discussions in two parts as field survey and laboratory based experiments.

4.1. Field Survey

The field survey resulted in very good description and situational analysis as a base for the laboratory based experimentation. The technical information obtained from household respondents on trends of sorghum, utilization for preparation of traditional CF. This in turn, served as basis to formulate CF from sorghum blended with chickpea and OFSP for preparation of nutritionally improved CF.

4.1.1. Socio-demographic characteristics of the study participants

The average range of the household respondent family size was from 4-6 (Table 6). The household education level in this study revealed that 4.8% attended secondary school, and majority of respondents were primary educated and illiterate (Figure 6). The proportion of illiteracy in the study area was 27.5% which was lower than the findings in Eshetu and Dula (2013) due to the household family size number in this study was smaller. The education level and family size were identified in the target study area for the child feeding practice and care giving. The larger family sizes were observed to increase in areas where there was a risk of malnutrition. This result was similar to the findings reported by Solomon and Zemene (2008). Due to overcrowding and inadequate feeding has been occurred as a risk factor for malnutrition in different studies as well (Haidar *et al.*, 2005). This supports the concept that non-nutritional factors should be essential components in the effort to reduce malnutrition in Ethiopia.

Table 6 Socio-demographic characteristics of the study participants

	Frequency	Percent
Family size		
3	27	13
4	43	20.8
5	40	19.3
6	45	21.7
7	28	13.5
8	16	7.7
9	7	3.4
10	1	0.5

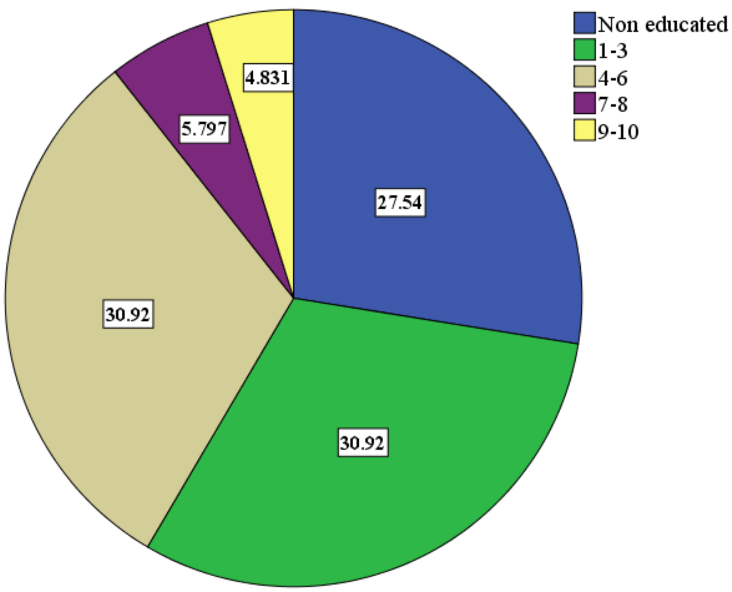


Figure 6 The study participants' educational background

As shown in Figure 7 about 81% of the respondents were using sorghum in their diets by mixing with other grains and 14.5% were consumed sorghum alone. The survey results indicated that only 48.3% of the respondents were consumed chickpea as different type of foods. No one of the respondents was used OFSP as a food and 99 % of the respondents had no awareness about the nutritional value and the palatability of OFSP variety. However, after a brief on importance of the OFSP about 84% of the respondents are interested to grow OFSP, if they have the opportunity to get the cuttings. This implies that nutrition education through crop diversification as integral part of the agriculture and health extension packages may create awareness on food diversification and prevention of malnutrition in the community.

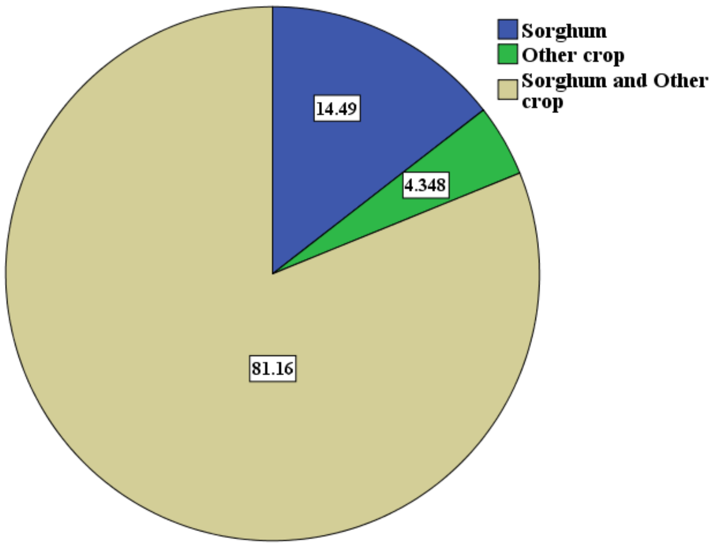


Figure 7 Sorghum consumption trained in Loma districts

Traditionally, the respondents prepared many types of food from sorghum like *kita*, *injera*, porridge, gruel and *posose* for all family (Table 7). *Posose* is a traditional food prepared from sorghum and maize flour by mixing with butter. Most of the respondents commonly prepared *kita* and *injera* by blending sorghum with other grains or alone as shown in Table 7. The 85% of interviewed households blend sorghum with different grains for different purposes. Basically the farmers blend to improve the palatability of their food and increase the flour in content especially for *teff* to prepared *injera*. Based on their preference, the respondents blend sorghum grain with maize, *teff,* barley and some of the respondents used sorghum without mixing with other grains.

For consumption and preparation of those different traditional foods, about 57% of the respondents obtained the sorghum grain from the farm. The other 5.8% of the respondents purchased from the local market, while 37.2% of the respondents got from both local market and on farm. The farmers grow only the local red and white sorghum varieties for their food and local market.

Table 7 Traditional food prepared from sorghum, chickpea and mixed with different crops

		Frequency	Percentage (%)
1	Traditional food prepared from sorghum		
	- *Kita*	70	33.8
	- *Injera*	12	5.8
	- *Kita and Injera*	93	44.9
	- Porridge	22	10.6
	- Gruel	7	3.4
	- *Posose*	2	1
2	Sorghum mixed with different crops		
	- Maize	86	41.5
	- Teff	64	30.4
	- Barley	8	3.9
	- Maize and teff	18	8.7
	- No mix (sorghum alone)	31	15
3	Type of food prepared from chickpea		
	- Roasted product (*Kolo)*	77	37.2
	- Boiled product *(Nifro)*	5	2.4
	- Both product *(Kolo* and *Nifro)*	18	8.7
4	Chickpea mixed with different crops		
	- Groundnut	20	9.7
	- Barley	1	0.5
	- Wheat	3	1.4
	- No mix	76	36.7

As presented in Table 7 the respondents consumed chickpea by roasting (*kolo)* and boiling (*nifro)* with other crops and alone. Around 51.7% of the respondents did not consumed chickpea. This was due to lack of awareness about the nutritional value of chickpea. Many of the respondents do not have the awareness on the nutritional value and anti-nutritional factors of sorghum and chickpea. Based on the survey results, all respondent had no awareness and the rest of them had limited awareness about the nutritional value and deficiency of sorghum and chickpea. However, they perceived that red sorghum has better nutritional quality than the white one; and chickpea with the seed coat has better nutritional quality than de-hulled. According to Abera (2003), tannins have the ability to precipitate certain proteins they combine with digestive enzymes thereby making them unavailable for digestion. Binita and Khetapaul (1997) reported that tannins form insoluble complexes with proteins, carbohydrates and lipids leading to a reduction in digestibility of these nutrients. The major ANFs (tannin) located in the seed coat of chickpea (Shahidi and Naczk, 1995). Similarly, Rao and Deosthale (1982) found that de-hulling resulted in 75–93% loss of tannin content. Hence, removal of seed coat is used to reduce the anti-nutritional effect of tannin and improve the nutritional quality of chickpea foods.

4.1.2. Complementary Food Preparation

Appropriate complementary feeding promotes growth and prevents stunting among children between 6 and 24 months of age. Inadequate knowledge about food preparation and feeding practices is often to have a greater determinant of malnutrition. The interviewed female farmers have an interest to participate on training of baby food preparation, if they get an opportunity.

In Dawro zone, mothers traditionally prepared food for their baby as gruel and porridge or both of them. As shown in Table 8, around 82.6% of the interviewed mothers were experienced on preparation of gruel, 2.9% porridge and 14.5% of them know about how to prepare gruel and porridge for their children from red sorghum, red *teff*, maize and groundnut by mixing together or red sorghum alone.

Table 8 Child food preparation habit

	Frequency	Percentage
Baby food preparation		
- Gruel	171	82.6
- Porridge	6	2.9
- Both	30	14.5

This study showed that higher percentage of the respondents prepared gruel (thin porridge) for the children from red sorghum alone or mixing with other crops. Consequently, children were fed with low nutrient dense complementary food. Lack of nutrient dense CFs was one of the common problems accounting for decline in satisfactory growth pattern in children (Lartey *et al*., 1999). FAO (2001) reported that staple foods such as millet, maize and sorghum are high in starch hence absorbed a lot of water during cooking which make them bulky and hence, infants need to consume large quantities to get enough energy and nutrients. However, it is difficult due to small stomach of the children. This problem can be solved, if families feed children with CF prepared from germinated cereal flour (Ikujenlola and Fashakin, 2005).

Most of the household respondents' prepared CFs from red sorghum alone because red sorghum served as the main grain for infant food in the district (Figure 8). Which are cereals like sorghum protein quality was poor due to lack of some essential amino acids (lysine and tryptophan). The other major limitation in the use of red sorghum (high tannin sorghum) is the presence of tannin at high concentration (Kumar *et al*., 2005). According to Gilani *et al.* (2005) high levels of tannins in cereals, such as sorghum, result in significantly reduced protein and amino acid digestibility. However, they could be eliminated or reduced by processes such as soaking, de-hulling, germination and fermentation (Sandberg, 2002; Ugwu and Oranye, 2006). Hence, this study was initiated to improve the nutritional quality of sorghum based CF through blending with chickpea and OFSP.

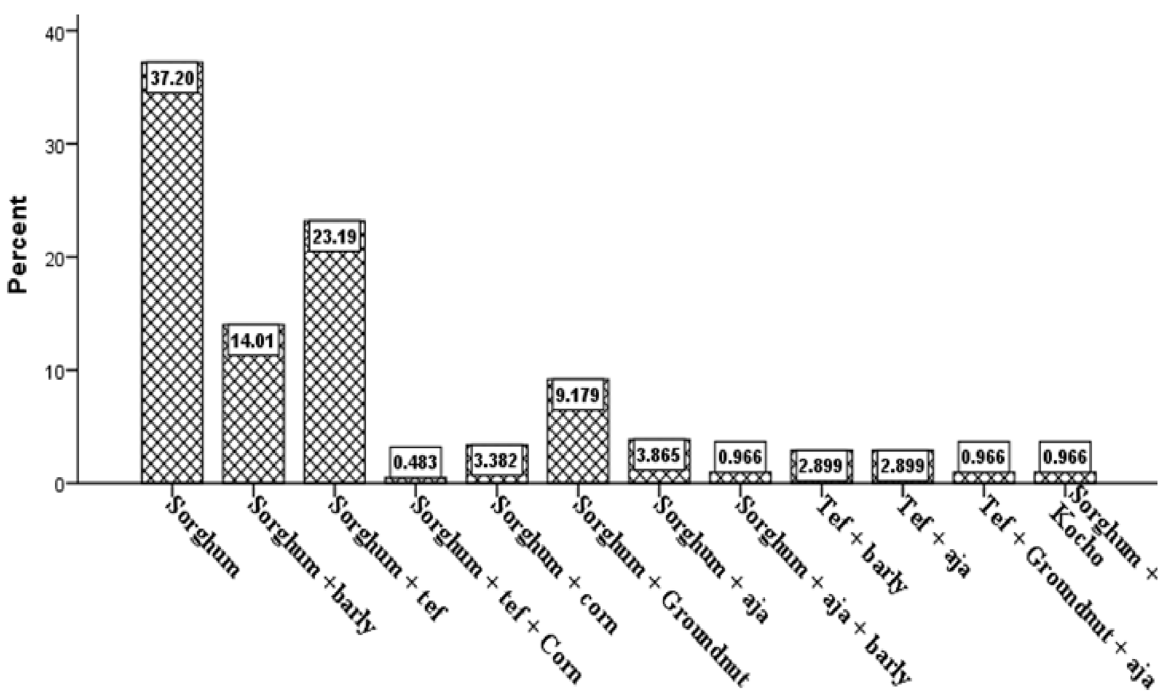


Figure 8 Different grain mixtures to prepare complementary food for infants in Loma district

4.2. Sorghum Based Complementary Food Product Development at Laboratory

The sorghum based CF ingredients was selected based on the survey result. In the study area most of the households were used red sorghum grain as a main food for infants. The ANFs found in red sorghum grain was very high specially tannins. Hence, to improve the tannin concentration tannin free sorghum was selected for the current study. Chickpea also selected to improve the protein content of the CF. As indicated many researcher OFSP also has high potential to improve the Vitamin A content of the product.

Data on proximate composition (moisture, ash, crude protein, crude fat, crude fiber and carbohydrate), micronutrients (iron, zinc, calcium and β-carotene content), anti-nutritional factors (tannin, phytate), functional properties (viscosity, water absorption capacity, bulk density) and sensory evaluation of the porridge were collected. The results of all response variables were described and presented in Table and Figure.

4.2.1. Proximate composition

Table 9 indicates the proximate composition (moisture, ash, crude protein, crude fat, crude fiber and carbohydrate) of porridge flours, each of the three ingredients and the local red-sorghum as control. Models for all proximate compositions were fitted indicated that the lack-of-fit p-values were not significantly different at 5% probability level or ($P<0.05$). Diagnostic tools like normality plot of residuals indicated that the residuals of all the response variables are normally distributed.

Moisture content

The moisture content of porridge flour varied between 4.98 to 6.5% whereas the moisture content of sorghum, chickpea, OFSP and local red sorghum flour was measured 5.33, 5.53, 6.08 and 10.19% respectively (Table 9). The moisture content of porridge sample showed highly significant difference ($P<0.01$) between sorghum and OFSP interaction in quadratic model (Appendix Table 1). This might be related to the high moisture content of OFSP as compared to other ingredients analyzed separately. Similarly, Gebremedhin *et al.* (2013)

reported that the moisture content of the blending increased with the increment of OFSP flour proportion in cereal flour.

Table 9 Proximate composition of porridge and ingredients flour samples

Porridge components			Proximate composition						
Sorg.	Chick	OFSP	M.C (%)	C.P (%)	C.fat (%)	C.F (%)	Ash (%)	CHO (%)	Energy (k cal/100g)
40.0	35.0	25.0	6.50	12.37	4.77	1.87	2.28	72.21	381.25
47.5	27.5	25.0	5.90	11.72	4.28	2.07	2.22	73.81	380.64
47.5	27.5	25.0	5.95	11.59	4.21	2.08	2.14	74.03	380.37
47.5	27.5	25.0	6.00	11.55	4.14	2.51	2.07	73.73	378.38
55.0	20.0	25.0	5.78	11.32	4.03	2.22	2.20	74.45	379.35
55.0	20.0	25.0	6.09	11.08	3.95	2.35	2.15	74.38	377.39
52.5	25.0	22.5	5.54	11.41	4.23	2.42	2.08	74.32	380.99
45.0	35.0	20.0	5.55	12.47	4.89	1.57	2.04	73.48	387.81
50.0	30.0	20.0	5.54	12.27	4.64	1.89	2.07	73.59	385.20
47.5	35.0	17.5	5.03	12.68	4.82	1.78	1.99	73.71	388.94
47.5	35.0	17.5	4.98	12.78	4.86	1.68	1.86	73.85	390.26
55.0	27.5	17.5	5.60	12.23	4.58	1.57	1.96	74.06	386.38
55.0	27.5	17.5	5.43	11.91	4.47	1.46	1.98	74.76	386.91
50.0	35.0	15.0	5.12	12.91	5.01	1.36	1.91	73.69	391.49
55.0	30.0	15.0	5.02	12.78	4.76	1.25	1.93	74.26	391.00
55.0	35.0	10.0	5.10	13.73	5.12	1.15	1.88	73.02	393.08
100	-	-	5.33	10.46	3.49	1.04	1.31	78.37	386.73
-	100	-	5.53	18.69	5.61	0.94	2.19	67.04	393.41
-	-	100	6.08	5.23	1.26	2.89	3.87	80.67	354.94
Local sorghum			10.19	8.57	3.42	1.35	1.52	74.95	364.86

Sorg.= Sorghum Chick= Chickpea OFSP= Orange fleshed sweet potato M.C= Moisture content
C.P= Crude protein C.fat= Crude fat C.F= Crude fiber kcal= kilo calorie

The moisture content of all porridge sample and the ingredient was within FAO/WHO recommended safe limit (<10%) except for the local sorghum, as higher moisture may affect the storage quality of the foods. High moisture content in foods has been shown to encourage microbial growth (Temple *et al*., 1996). This is an important consideration in local feeding methods in developing countries because most mothers often prepare large quantities of dry infant foods and keep in containers, to avoid frequent processing in order to have spare time and energy for other domestic activities (Makinde and Ladipo, 2012).

The regression model for moisture content was represented in (Eq. 13) as indicated in quadratic model with three variables.

$$y = 21.5x_1 + 9.9x_2 + 54.7x_3 - 46.1x_1x_2 - 114.4x_1x_3 - 15.5x_2x_3 \text{…………………Eq.13}$$

Where, y= Moisture content $\boldsymbol{x_1}$=Sorghum $\boldsymbol{x_2}$=Chickpea $\boldsymbol{x_3}$= OFSP

Ash Content

Table 9 indicates the ash content of porridge sample and the interaction between sorghum and OFSP were significantly different (p< 0.05) (Appendix Table 1). The ash content of the porridge sample varied between 1.86-2.28% and its content increases as the amount of OFSP increases in the composite flour. This might be due to the high ash content of OFSP as compared to other ingredients. Gebremedhin *et al.* (2013) reported that the ash content of composite flour increased with the increment in the proportion of OFSP flour which is inline to this study finding.

Details on the ash content of each flour ingredient are presented in Table 9. The OFSP flour mean ash content (3.87%) was higher compared to that of sorghum and chickpea (1.31% and 2.19%) indicating its high amounts of minerals. The result of sorghum ash content was similar to the report by Makinde and Ladipo (2012) in their study of the physico-chemical properties of of sorghum based complementary food. The highest value of ash content recorded in OFSP flour indicates that OFSP has a good potential to prepare a CF that supports mineral requirement of the infants' complementary feeding period. A similar result was reported by Udensi *et al*. (2012). The author reported higher ash content, indicating higher levels of minerals in the diet of OFSP.

The regression model for ash content was represented in (Eq. 14) as indicated in quadratic model with three variables.

$$y = 5.13x_1 + 4.57x_2 + 12.54x_3 - 12.22x_1x_2 - 21.80x_1x_3 - 7.08x_2x_3 \text{…….Eq. 14}$$

Where: y= Ash $\boldsymbol{x_1}$=Sorghum $\boldsymbol{x_2}$=Chickpea $\boldsymbol{x_3}$= OFSP

Crude protein content

The protein content of the ingredient flour *i.e.* sorghum, chickpea, OFSP and local red sorghum was shown in (Table 9). The highest (18.69%) protein content was reported in chickpea flour samples which assumed to be promising potential as a good source of plant protein. The chickpea flour protein content in this study was in a range which is reported by Wood and Grudak (2007) from (16.7 to 30.57%). Chickpeas are good source of protein. Which, it improves the composite flour protein contents. The sorghum protein content (10.46%) recorded in this study is similar to the result reported by Shimelis *et al.* (2009). The protein content of OFSP flour sample recorded (5.23%) in this study is higher (1.30±0.22 and 4.62 ±0.09%) than the result reported by Lieghton (2007) and Gebremedhin *et al.* (2013). Those researchers found that lower protein content of OFSP flour on their study of nutrient content of OFSP and OFSP enriched cereal flour. This variation might be observed due to difference in type of product, variety used in the flour making (Gebremedhin *et al.*, 2013).

The protein content of porridge samples was ranged from 11.08 to 13.73% (Table 9). The protein content was showed significant difference ($P<0.05$) in the porridge samples was observed in the interaction between sorghum with OFSP and chickpea with OFSP (Appendix Table 1). The contour graph (Figure 9) indicates that the protein content of porridge samples increased with an increase in the proportion of chickpea flour. This is because the high amount of protein in chickpea flour. Dejene (2010) indicated that chickpea has good protein content approximately (20-30%) it depends on the variety. While opposite trend was observed with an increase in the proportion of OFSP flour in the porridge of composite flours. This result occurs because of the low protein content in OFSP (Sanoussi *et al*., 2013). A parallel increase in the protein content of porridge samples with an increase in the amount chickpea in composite flours is attributed to the high protein content of legumes (chickpea). Shahzadi *et al*. (2005) reported that legumes with high protein content widely used as composite flour in the product development; to improve the protein content of cereals. Aziah *et al*. (2012) who observed that an increase in the protein content with corresponding increase in the proportion of chickpea flour (35%) supplementation in cereal flour during the production of cookies. Moreover, Saleh *et al.* (2012) reported that substitution levels of the chickpea flour increased from 5 to 15% in cereal flour it increases the crude protein content biscuit product from 8.60

to 10.18%. Those findings showed that legume seeds are good sources of protein and other nutrients for human consumption and that their utilization in infant complementary food and other food products has been improved nutrition problems among low income group.

The recommended daily allowance of protein was 11[+] g/day for 7 to 12 months and 13 g/day for 13 to 24 months life stage (Food and Nutrition Board, 2005). To meet the daily requirement 100 g per day of the complementary porridges (as served) would be required. The red sorghum contain lower protein content about 8.57% when compare with the current study. Hence, the current complementary food improves from 2.51 to 5.16%. From this study, it is observed that the protein content of sorghum flour; both *Meko* variety and local red sorghum is lower when considered separately. But an increase in the protein content was recorded in the porridge samples prepared from blends of different ingredients like chickpea in addition to sorghum flour. Therefore, the result recorded in the protein content of porridge samples prepared from blends of sorghum, chickpea and OFSP flour in the present study revealed that addition of legumes like chickpea is a potential way to increase the nutritional value of traditional Ethiopian complementary foods prepared from sorghum flour. Similar result was recorded in the composite flours study conducted by Yewelsew *et al.* (2006) who reported combination of cereals with legume proteins would provide better overall essential amino acid balance, helping to overcome the world protein calorie malnutrition problem.

The regression model for protein was shown by (Eq. 15) indicating quadratic model with three variables;

$$y = 17.80x_1 + 28.79x_2 + 37.60x_3 - 23.88x_1x_2 - 61.39x_1x_3 - 54.29x_2x_3 \ldots\ldots\ldots\ldots \text{Eq. 15}$$

Where, y=Crude protein, $\boldsymbol{x_1}$=Sorghum $\boldsymbol{x_2}$=Chickpea $\boldsymbol{x_3}$= OFSP

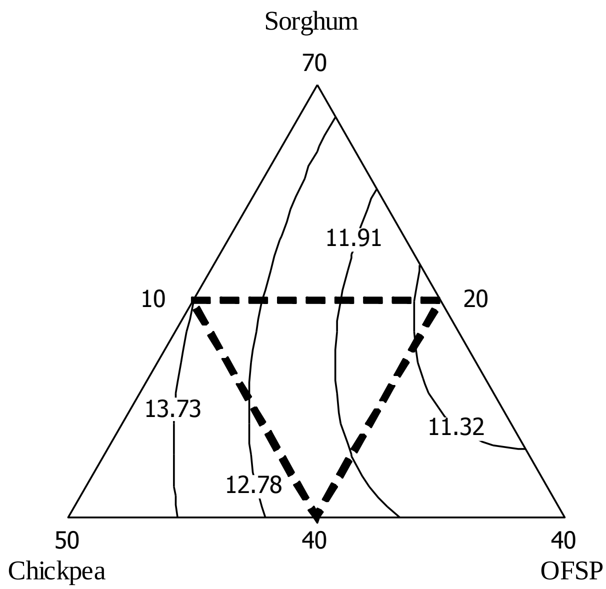


Figure 9 Blending effect on the protein content of porridge indicated by mixture contour plot

Crude fiber content

The fiber content of porridge samples from 16 different formulations was varied between 1.15 to 2.51% (Table 9). There was no statistically significant difference ($P \geq 0.05$) between different composite porridge. The higher fiber content was observed in porridge samples prepared from 47.5% sorghum, 27.5% chickpea and 25% OFSP. The result also indicated that the fiber content of porridge sample showed an increasing trend with parallel increase in the proportion of OFSP flour. This result was in agreement with the finding of Singh *et al*. (2008) showed an increase in the fiber content of the product as the OFSP flour increases in composite flour. This result occurs because of the high fiber content of OFSP and compared to sorghum and chickpea (Gebremedhin *et al*. 2013). Hence, incorporating OFSP in sorghum based complementary food improves the crude fiber content. Lee *et al*. (2007) reported that dietary fiber has a beneficial effect on bowel transit time, affects glucose and lipid metabolism, reduces the risk of colorectal cancer, and stimulates bacterial metabolic activity.

The regression model for crude fiber was shown by (Eq. 16) as indicating quadratic model with three variables;

$y = -10.22x_1 - 6.11x_2 + 6.81x_3 + 37.43x_1x_2 + 33.94x_1x_3 - 26.34x_2x_3$……..Eq. 16

Where: y= Crude fiber, $\boldsymbol{x_1}$=Sorghum $\boldsymbol{x_2}$=Chickpea $\boldsymbol{x_3}$= OFSP

Crude fat

The crude fat content of sorghum flour, chickpea flour, OFSP flour and local red sorghum fat content was shown in Table 9. The crude fat content of sorghum flour recorded in this study was found in between the values 3.37-3.67% which is reported by Shimelis *et al*. (2009). On the other hand the higher crude fat content of sorghum flour (4.12%) was reported by Makinde and Ladipo (2012). This variation may be occurs due to the variety and/or processing effects.

The fat content of 16 porridge sample was varied between 3.95- 5.12% in composite flours porridge sample prepared from 55% sorghum, 20% chickpea and 25% OFSP; 5.12% in porridge samples formulated from 55% sorghum, 35% chickpea and 10% OFSP. Significant difference ($P<0.05$) in the fat content of 16 porridge samples was observed between sorghum with chickpea interaction as shown in the (Appendix Table 1). The highest fat content in the porridge sample comprising of high amount of chickpea is attributed to high fat content of chickpea flour as compared to the other ingredients. Therefore, enrichment of cereals and root crops with legumes improve the fat content of complementary food of infant and young children with very high fat requirement to compensate glucose deficiency due to high body activity at this particular developmental period. Similar result was reported by Shahzadi *et al.* (2005) in composite flour consisting of chickpea. Partial substitution of the composite flour with high amount of OFSP flour in the formulation reduces the fat content of the product (Gebremedhin *et al*., 2013).

However, when compare the current study result with the RDA; the fat contents in 100 g of all the t16 blended diets (3.95- 5.12 %) did not meet the RDA 30-31 g/per day for all life stage infants. The red sorghum also contain lower fat 3.42 % content about 8.57% when compare with the current study and RDAs. To improve or to meet the fat content of the current product and red sorghum need to supplement with fat rich products like milk and/or egg.

The amount of fat content was shown in mixture contour graph (Figure 10) and the regression model for crude fat was shown as (Eq. 17) indicating quadratic model with three variables.

$$y = 8.55x_1 + 17.14x_2 - 1.19x_3 - 26.50x_1x_2 - 7.03x_1x_3 - 0.63x_2x_3 \ldots\ldots\ldots\ldots\ldots\ldots \text{Eq. 17}$$

Where, y= Crude fat, $\boldsymbol{x_1}$=Sorghum $\boldsymbol{x_2}$=Chickpea $\boldsymbol{x_3}$= OFSP

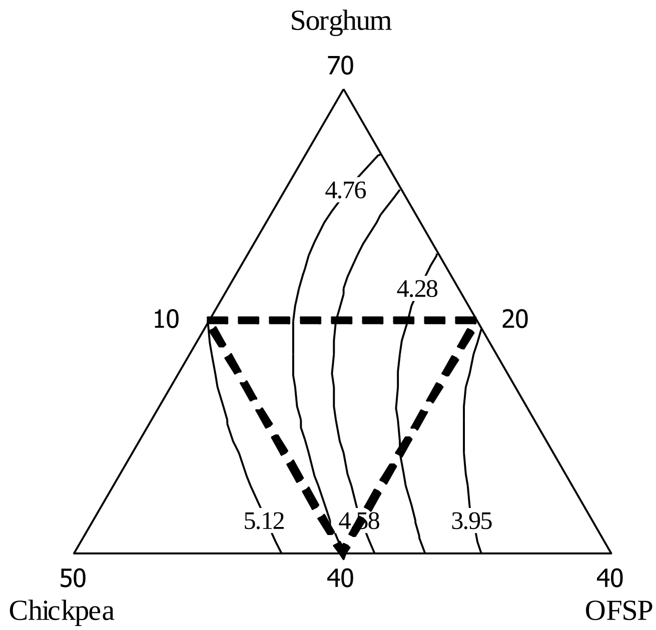


Figure 10 Blending effect on composite flours porridge fat content indicated by contour plot

Utilizable Carbohydrate

The utilizable carbohydrate content of sorghum, chickpea and OFSP flour was shown in Table 9. The utilizable carbohydrate content of porridge sample varied between 72.21 to 74.76%. The carbohydrate content of sorghum flour obtained in this study was comparable with reported 74.68% by Mohammed *et al*. (2011). While lower than the value 76.94 % reported by Shimelis *et al*. (2009). This variation may be due to the germination time and variety with different experimental condition respectively.

Highly significant difference (P<0.01) in utilizable carbohydrate content of 16 composite flour porridge samples was observed in the interaction between sorghum and OFSP and significant difference (P<0.05) in the interaction between chickpea and OFSP in quadratic and linear model. The lowest carbohydrate content (72.21 %) was recorded in porridge samples formulated with sorghum 40 %, chickpea 35 % and OFSP 25 % while the highest (74.76 %) was recorded in porridge samples formulated from sorghum 55 %, chickpea 27.5 % and OFSP 17.5 %. This finding indicated that the utilizable carbohydrate content increment with parallel increase in the proportion of sorghum flour. This is because the high amount of carbohydrate found in sorghum flour. Yusufu *et al*. (2013) indicated that sorghum flour has higher carbohydrate content around 78%. However, as the level of OFSP and chickpea flour increased the carbohydrate content of the composite flours porridge decreased. This indicated that sorghum was the main contributor to the carbohydrate content in porridge as it was reported by Gebremedhin *et al*. (2013). This might be due to the percentage of the OFSP in the composite flour is low as compared to the sorghum flour because sorghum is the main grain in this developed food or product.

The regression model for utilizable carbohydrate was shown by (Eq. 18) as indicating in quadratic model with three variables.

$$y = 57.19x_1 + 45.74x_2 - 10.49x_3 + 71.32x_1x_2 + 170.70x_1x_3 + 102.58x_2x_3 \text{ ....Eq. 18}$$

Where: y= Carbohydrate, $\boldsymbol{x_1}$=Sorghum $\boldsymbol{x_2}$=Chickpea $\boldsymbol{x_3}$= OFSP

Gross Energy

The gross energy content of sorghum flour, chickpea flour, OFSP flour and local red sorghum flour was shown in (Table 9). The gross energy of porridges samples were varied from 377.39 to 393.08 kcal/100g. The gross energy of germinated sorghum flour observed in this study comparable with the value reported by Mohammed *et al*. (2011) and Elemo *et al*. (2011).

Significant difference (P<0.05) was observed in the gross energy content of composite flours porridge sample between sorghum and OFSP interaction, in linear model and did not show significant difference (P≥0.05) in the other interaction. The higher gross energy content was observed in porridge sample prepared from a formula sorghum 55%, chickpea 35% and OFSP 10% and the lower energy content was observed in porridge sample prepared from a formula sorghum 55%, chickpea 20% and OFSP 25%. This result indicated that the energy content of porridge sample prepared from a formula consisting of high proportion chickpea flour may be attributed to the high fat content of chickpea flour. Onabanjo *et al.* (2009) in his study on characteristics of complementary food observed that the high fat content of legume and oil crops flour further increased the energy density of the products developed from different formulas. The energy content declined with the increment of OFSP flour proportion increases in the composite flour due to the low fat and protein content of OFSP (Sanoussi *et al*., 2013).

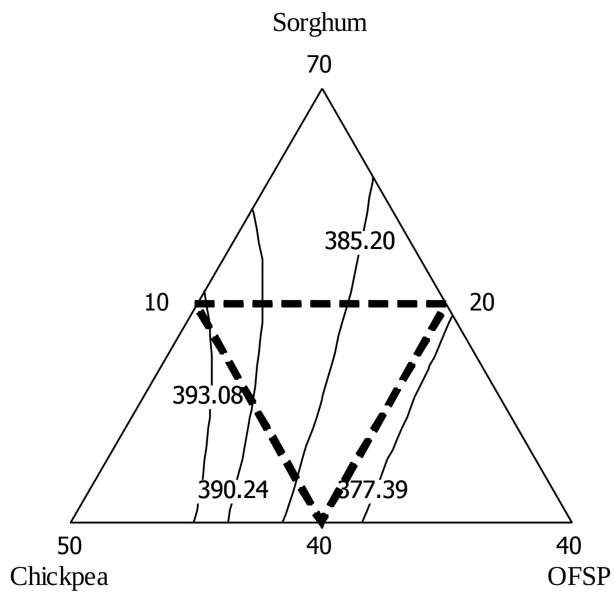


Figure 11 Blending effect on gross energy of composite flours porridge in mixture contour plot

The current total energy requirement estimated for healthy breastfed infants is of approximately 615 kcal/day from 6 to 8 months of life, 686 kcal/day from 9 to11 months and 894 kcal/day from 12 to 23 months (Dewey and Brown, 2003; Daelmans *et al*., 2003). Around 156-237 g per day of the complementary porridges would be required to meet the required energy for infants depending their age. Adding foods containing more lipids to the porridges would be beneficial to increase energy density and provide needed nutrients (Dewey and Brown, 2003).

The regression model for gross energy was shown by (Eq.19) as indicated in quadratic model with three variables

$$y = 376.93x_1 + 452.38x_2 + 97.71x_3 - 48.72x_1x_2 + 373.92x_1x_3 + 198.79x_2x_3 \text{.........Eq. 19}$$

Where, y= Gross energy, $\boldsymbol{x_1}$=Sorghum $\boldsymbol{x_2}$=Chickpea $\boldsymbol{x_3}$= OFSP

4.2.2. β- Carotene Content

The β-carotene content of OFSP was 1646.2 µg/100 g. While the β-carotene content of composite flours porridge sample was varied between 246.93 to 670.46 µg/100 g as represented in (Table 10). Models for β-carotene content were fitted indicated that the lack-of-fit p-values were not significantly different at 5% probability level or ($P<0.05$). Diagnostic tools like normality plot of residuals indicated that the residuals of the response variables are normally distributed.

Table 10 β-carotene content of composite flours porridge µg/100g

Porridge components			β-Carotene
Sorg.	Chick.	OFSP	
40.0	35.0	25.0	642.63
47.5	27.5	25.0	670.46
47.5	27.5	25.0	629.81
47.5	27.5	25.0	647.42
55.0	20.0	25.0	624.70
55.0	20.0	25.0	612.61
52.5	25.0	22.5	546.61
45.0	35.0	20.0	450.95
50.0	30.0	20.0	422.54
47.5	35.0	17.5	393.42
47.5	35.0	17.5	390.69
55.0	27.5	17.5	378.29
55.0	27.5	17.5	329.24
50.0	35.0	15.0	313.25
55.0	30.0	15.0	264.01
55.0	35.0	10.0	246.93
100	-	-	NA
-	100	-	NA
-	-	100	1646.22
Local sorghum			NA

Where: Sorg.= Sorghum Chick= Chickpea OFSP= Orange fleshed sweet potato NA= Not analyzed

The retinol activity equivalent (RAE) is based on the assumption that 12 μg of dietary ß-carotene from food would be converted to the equivalent of 1 μg retinol (Food and Nutrition Board, 2005). Assuming that 13.97 % of the vitamin A activity contributed by OFSP ß-carotene. The supplemented complementary foods provided from 20 to 55μg RAE/100 kcal as feed. Hence, the current complementary food improves the local red sorghum complementary food by providing 13.97 % of the vitamin A content.

The β-carotene content was showed highly significant difference (P<0.01) in16 composite flours porridge samples and also in the interaction between sorghum with OFSP and chickpea with OFSP in both linear, quadratic model was vary as indicated (Appendix Table 2). The increment of β-carotene content was parallel increase in the proportion of OFSP flour (Figure 12) due to the high β-carotene content of OFSP. This study was in agreement with previous investigation reported by Jaarsveld *et al*. (2006). Low *et al*., (2007) indicated that OFSP is a particularly promising food; because of β-carotene levels are extremely high in many varieties (100–1600 mg retinol activity equivalent (RAE)/100 g for varieties in Africa. The other researcher; Kapinga *et al*. (2009) also reported that colored variety of sweet potato could be improve dietary source of vitamin A in Sub-Saharan Africa. Hence, utilization of OFSP flour in complementary food formulation can be taken as promising strategy to tackle vitamin A deficiency with a high prevalence rate among infants and young children. Mitra (2012) indicated that consumption of orange-fleshed sweet potato can make a significant contribution in alleviating vitamin A malnutrition and combating night blindness (Vimala *et al*., 2011).

The regression model for β-carotene was shown by (Eq.20) in the quadratic model with three variables

$$y = -740\,x_1 + 142x_2 + 11617x_3 + 2916\,x_1x_2 - 10424\,x_1x_3 - 15789x_2x_3 \ldots\ldots\ldots\text{Eq. 20}$$

Where, y= β- carotene, $\boldsymbol{x_1}$=Sorghum $\boldsymbol{x_2}$=Chickpea $\boldsymbol{x_3}$= OFSP

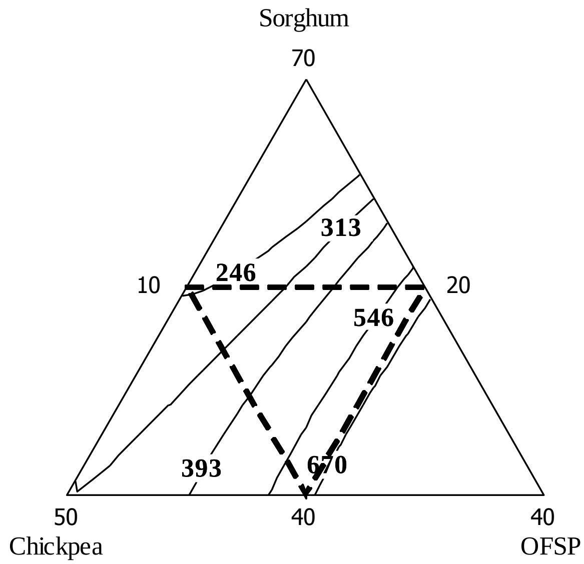


Figure 12 Blending effect on the β- carotene content porridge in mixture contour plot

4.2.3. Minerals content

The mineral content of all porridge samples and ingredients were presented in Table 11. Models for all minerals content were fitted indicated that the lack-of-fit p-values were not significantly different at 5% probability level or (P<0.05). Diagnostic tools like normality plot of residuals indicated that the residuals of all the response variables are normally distributed.

Iron Content

The iron content of sorghum flour, chickpea flour, OFSP flour and local red sorghum flour was shown in Table 11. The iron content of sixteen porridge samples was varied between 4.28 to 7.65 mg. The level of iron in sorghum based complementary food observed in this study were comparable (5.56-6.21 mg/100 g) with those reported by Mosha *et al*. (2000); Dewey and Brown (2003); Mosha and Vicent (2005). The iron content did not showed significant difference (P<0.05) between 16 porridge samples. Even though there was an increment in the iron content from 4.28 to 7.65mg/100g with an increase in proportion of sorghum flour and to some extent with the level of chickpea. This result observed because of high iron content was found in sorghum flour as compare to the other ingredients. Similarly Glew *et al*. (1997) indicated that sorghum is a good source of minerals like iron. However, the iron content declined with an increase in the proportion of OFSP. This can be evident from the fact that the iron content in OFSP flour was low as compared to the iron content of sorghum and chickpea.

The Fe content of the current study was ranged from 4.28 to 7.65 mg/100g where as the RDA for 6 to 12 month life stage infant was 11 mg/ day and 7 mg/day for 13 to 36 months life stage children. The blended product was meet 38.9 to 69.54 % of the RDA for 6 to 12 month life stage infants and 61.14 to 100% for 13 to 36 months life stage children in lower and higher value respectively. The local red sorghum was meet the RDA in all life stage infant and children but the bioavailability was affected by tannin concentration because it contains high tannin concentration.

The regression model of iron;

$y = 28.49x_1 + 37.25x_2 + 16.48x_3 - 87.45x_1x_2 - 65.88x_1x_3 - 59.88x_2x_3$……………Eq. 21

Where, y= Iron $\boldsymbol{x_1}$=Sorghum $\boldsymbol{x_2}$=Chickpea $\boldsymbol{x_3}$= OFSP

Table 11 Measured mineral content of porridge, individual flour and local sorghum mg/100g

Run	Porridge composition (%)			Mineral composition (mg/100g)		
	Sorg.	Chick.	OFSP	Iron	Zinc	Calcium
1	40.0	35.0	25.0	4.49	2.32	71.54
2	47.5	27.5	25.0	4.80	2.26	67.64
3	47.5	27.5	25.0	4.28	2.25	67.88
4	47.5	27.5	25.0	4.58	2.24	67.46
5	55.0	20.0	25.0	5.65	2.12	65.18
6	55.0	20.0	25.0	5.55	2.16	62.36
7	52.5	25.0	22.5	5.19	2.26	62.94
8	45.0	35.0	20.0	5.41	2.36	67.20
9	50.0	30.0	20.0	5.45	2.36	62.23
10	47.5	35.0	17.5	5.54	2.46	61.58
11	47.5	35.0	17.5	5.45	2.43	64.05
12	55.0	27.5	17.5	5.98	2.41	60.85
13	55.0	27.5	17.5	6.58	2.38	60.14
14	50.0	35.0	15.0	6.85	2.48	61.83
15	55.0	30.0	15.0	6.98	2.47	60.25
16	55.0	35.0	10.0	7.65	2.66	61.03
	100	-	-	7.69	2.57	36.77
	-	100	-	4.65	2.70	62.87
	-	-	100	3.18	0.72	99.91
	Local sorghum			13.87	2.53	35.13

Where: Sorg.=Sorghum Chick= Chickpea OFSP=Orange-fleshed sweet potato

Zinc content

Zinc content of sorghum, chickpea, OFSP and local red sorghum flour sample was represented in Table 11. The zinc content of sixteen porridge samples was varied 2.12 to 2.66 mg/100 g. The zinc content of the 16 blended porridges and the red sorghum flour were lower than values of RDA. Zinc contents in 100 g of the complementary food were calculated and compared with RDA; it meets 70.67 to 88.67 % of the RDA in all complementary food and the local red sorghum meet 84.3 %.

The zinc content showed highly significant difference ($p<0.01$) in quadratic model and between sorghum with OFSP interaction and did not shown significant difference in other interaction and in linear model. As indicated in the Figure 13a zinc content increased with an increase in the proportion of chickpea and sorghum flour. Hence, using chickpea and sorghum flour in food formulation improve the zinc content of the composite flour. Similarly, Wood and Grusak (2007) reported that chickpea has the potential to contribute to daily zinc intake and help to alleviate these problems of micronutrient malnutrition. However, the contradictory trend was observed with increasing proportion of OFSP flour in the composite flour. This can be evident from the fact that the zinc content in OFSP flour was low as compared to the zinc content of sorghum and chickpea. So, in this study sorghum and chickpea was a good source of zinc in composite flour.

The regression model for zinc;

$y = 2.872x_1 + 1.062x_2 + 5.214x_3 + 3.896x_1x_2 - 9.724x_1x_3 - 0.938x_2x_3$………….Eq.22

Where, y= Zinc $\boldsymbol{x_1}$=Sorghum $\boldsymbol{x_2}$=Chickpea $\boldsymbol{x_3}$= OFSP

Calcium content

The calcium content of sorghum flour, chickpea flour and OFSP flour was 36.77 mg, 62.87 mg, 99.91 mg and the local red sorghum flour 35.13 mg per 100g respectively in the present study. The calcium content in sixteen porridge samples was varied between 60.14 to 71.54 mg per 100g. The RDA for 6 to 12 months and 13 to 36 months was 270 mg and 500 mg per day respectively (Food and Nutrition Board, 2005). The current blended product was meet the

RDA for both life stage of infant and children was only 22.27 to 26.49% and 12 to 14 % respectively in all diets. The local red sorghum meets 7 to 13% of the RDA for both life stage groups. When compared the current blended product with the local red sorghum; the blended products have better calcium content but still it needs calcium fortification or enrichment with calcium rich agricultural product to meet the RDA for infant and children.

The calcium content was showed a significant difference (P<0.05) in the interaction between chickpea with OFSP in quadratic model and highly significant difference (P<0.01) in the interaction between sorghum with OFSP in linear model. As shown in Figure 13b the calcium content of porridge was increase with the increment of OFSP proportion in the composite flours porridge sample. The difference was observed due to the higher amount of calcium proportion found in the OFSP. Similar result was reported by Leighton (2007), was studied on the nutrient and sensory quality of orange-fleshed sweet potato. Hence, using OFSP flour in complementary food formula can be taken as promising food based strategy to improve the developed product.

The regression model for calcium;

$y = 77.4x_1 + 98.2x_2 + 423.9x_3 - 74.3x_1x_2 - 565.8x_1x_3 - 368.9x_2x_3$ ……………Eq. 23

Where, y= Calcium $\boldsymbol{x_1}$=Sorghum $\boldsymbol{x_2}$=Chickpea $\boldsymbol{x_3}$= OFSP

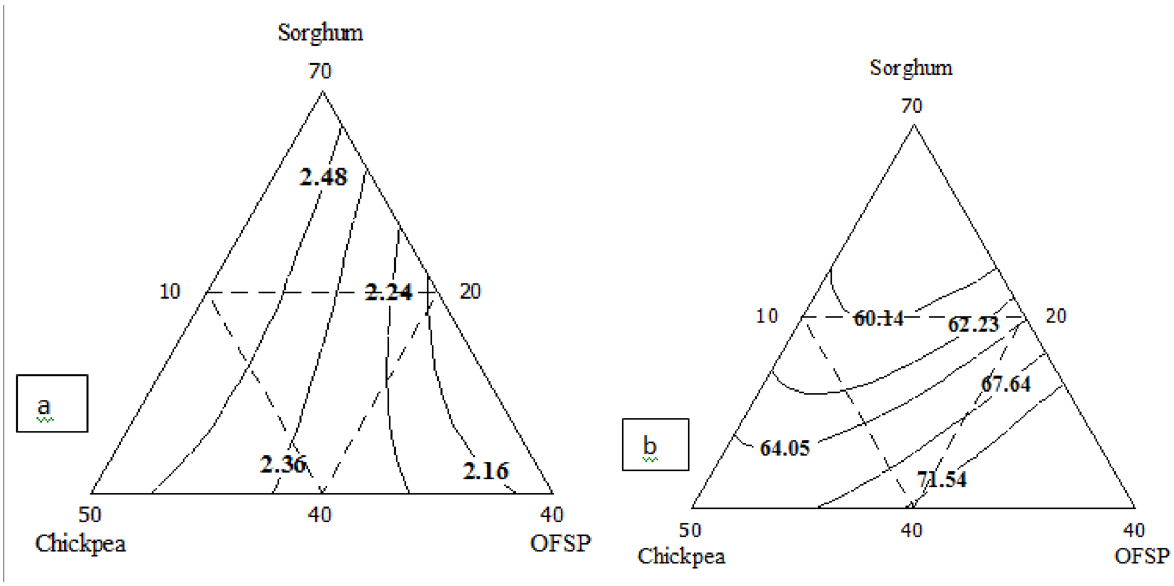


Figure 13 Effect of blending on the (a) zinc and (b) calcium content of composite flours porridge indicated by mixture contour graph

4.2.4. Anti-nutritional factors

The anti-nutritional factors (tannin and phytate) of ingredients and composite flours porridge sample were analyzed and the value was summarized in (Table 12). Models for anti nutritional factors were fitted indicated that the lack-of-fit p-values were not significantly different at 5% probability level or ($P<0.05$). Diagnostic tools like normality plot of residuals indicated that the residuals of all the response variables are normally distributed.

Table 12 Anti- nutritional factors of composited flours porridge and individual flours

Run	Porridge component (%)			mg/100 g	
	Sorghum	Chickpea	OFSP	Phytate	Tannin
1	40.0	35.0	25.0	99.50	16.80
2	47.5	27.5	25.0	95.94	15.06
3	47.5	27.5	25.0	100.56	14.58
4	47.5	27.5	25.0	103.79	14.58
5	55.0	20.0	25.0	109.33	12.76
6	55.0	20.0	25.0	113.48	12.58
7	52.5	25.0	22.5	104.47	12.39
8	45.0	35.0	20.0	100.39	13.31
9	50.0	30.0	20.0	100.10	12.21
10	47.5	35.0	17.5	109.79	11.84
11	47.5	35.0	17.5	108.68	11.64
12	55.0	27.5	17.5	112.17	10.55
13	55.0	27.5	17.5	110.71	10.19
14	50.0	35.0	15.0	106.75	10.74
15	55.0	30.0	15.0	113.02	9.82
16	55.0	35.0	10.0	115.13	8.74
	100	-	-	161.96	1.29
	-	100		78.40	14.16
	-	-	100	48.76	30.70
	Local sorghum			168.88	3946.94

Where: OFSP= Orange-fleshed sweet potato

Phytate

Significant difference ($p<0.05$) was observed in phytate content of sixteen porridge samples in the interaction of sorghum with chickpea while there was no significant difference ($P\geq0.05$) in the other interactions. The phytate content increased from 95.94 to 115.13mg/100g as sorghum flour proportion increased in the composite flour from (40-55%). This might be due to the high amount of phytate content found in sorghum flour than chickpea and OFSP. Shimelis *et al*. (2009) reported that the phytate content in germinated *meko* sorghum variety is 203.76mg/100g in which it is higher than the result recorded in present study. This author also reported that germination of sorghum flour reduced phytate content by 36.94 and 56.18% depending on the germination time for 36 and 48 hrs respectively.

The effect of blending ratio on phytate content was shown in mixture contour graph (Figure 14) and the regression model was shown by (Eq. 24) as indicating in quadratic model with three variables.

$y = 320x_1 + 512x_2 + 100x_3 - 1110x_1x_2 - 322x_1x_3 - 512x_2x_3$ ………………….........Eq. 24

Where: y= phaytate $\boldsymbol{x_1}$=Sorghum $\boldsymbol{x_2}$=Chickpea $\boldsymbol{x_3}$= OFSP

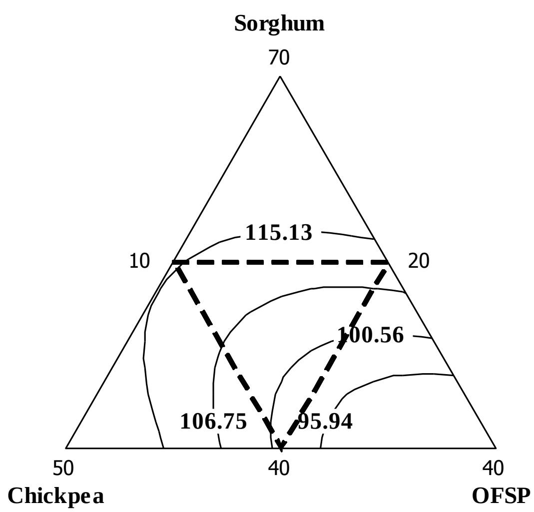


Figure 14 Blending effect on the phytate concentration of porridge in mixture contour plot

Tannin

The tannin content of composite flours porridge samples showed highly significant different (P<0.01) sorghum with OFSP interactions and a significant different (P<0.05) in chickpea with OFSP interactions in quadratic model. The variation in tannin content might be related to higher tannin content of OFSP flour as compared to the tannin content in chickpea and sorghum flour. Esther and Ignitiatus (2010) also reported that tannin content in two OFSP varieties ranged from 0.20-0.25%. In present study the tannin content of chickpea was observed lower this might be due to processing effect (de-hulling). According to Mittal *et al*. (2012) ANFs is mainly concentrated in the seed coat of the legume, thus preliminary de-hulling constitutes the simplest way for their removal. Hence, by removing seed coat from legume we can minimize high tannin concentration from complementary food.

The tannin content of local red sorghum (3946.94 mg/100g) was higher than *Meko* sorghum (1.29 mg/100g) variety. The tannin content of *Meko* sorghum flour was found to be 1.29 mg/100g but Shimelis *et al*. (2009) in his study on improvement of energy and nutrients density of sorghum based complementary food reported that the tannin content in *meko* variety of sorghum flour to be below detection limit. This variation might be due to difference in type of the product and processing methods used in the germination time. The tannin content of chickpea in this study is in ranges reported by Petterson *et al.* (1997) and Salgado *et al.* (2001). They observed that the tannin content in *desi* chickpea was varied from 10mg to 90mg/100g.

According to Adeparusi (2001) tannin affect protein digestibility, adversely influencing the bio-availability of non-haem iron leading to poor iron and calcium absorption. It also affects the carbohydrate component of diet resulting in reduced energy value of a diet containing tannins. In this study the result formulation and cooking was minimizing the phytate concentration in the final product. Similar result was reported by Alajaji and El-Adawy (2006) those authors observed tannin and phytic acid in chickpea were significantly reduced by cooking.

The regression model for tannin content was shown by (Eq. 25) indicating in quadratic model with three variables.

$y = 7.6x_1 + 7.0x_2 + 133.8x_3 + 1.6x_1x_2 - 171.1x_1x_3 - 59.6x_2x_3$……………..Eq. 25

Where, y= Tannin, $\boldsymbol{x_1}$=Sorghum $\boldsymbol{x_2}$=Chickpea $\boldsymbol{x_3}$= OFSP

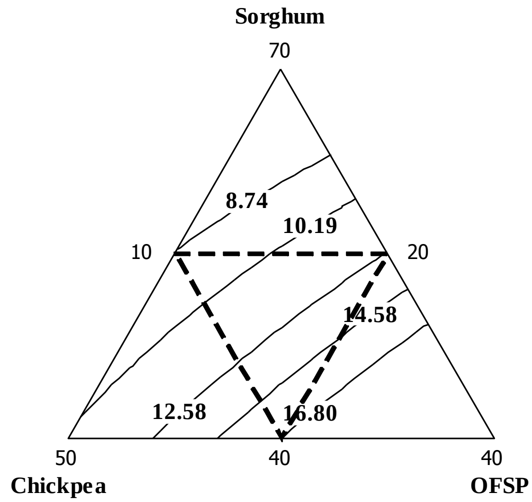


Figure 15 Blending effect on the tannin content of porridge in mixture contour plot

4.2.5. Functional properties

The functional properties (bulk density, WAC and viscosity index) of composite flour and individual ingredients were summarized in Table 13. Analysis of variance results is also summarized in Appendix Table 3. Models for functional properties were fitted indicated that the lack-of-fit p-values were not significantly different at 5% probability level or ($P<0.05$). Diagnostic tools like normality plot of residuals indicated that the residuals of all the response variables are normally distributed.

Bulk Density

The bulk density of the composite flours porridge was varied between 0.81-0.84 g/cm^3. There was no statistically significant difference ($P\geq0.05$) between all composite flours and porridges. But as shown in (Figure 12a) the bulk density of porridge sample showed an increasing trend with the increment of the proportion of sorghum flour and chickpea flour. Masood and Rizwana, (2010) indicated that the bulk density was increased in the composite flour with soybean protein content. Similar results reported by Malomo *et al*. (2011) who indicated that bulk density of composite flour of yam with soybean increased as the amount of soybean increased. This result may be observed due to the protein content found in sorghum and chickpea flour was higher as compared with the OFSP. The low bulk density of the blends is an advantage in the formulation of complementary foods (Akubor and Ukwuru, 2003).

The regression model for bulk density was shown by (Eq. 26) indicating in quadratic model with three variables.

$$y = 0.00945x_1 + 0.0105\,x_2 + 0.0075x_3 - 5.10x_1\,x_2 - 4.0099x_1x_3 - 4.985\,x_2x_3 \text{…....Eq.26}$$

Where: y= Bulk density $\boldsymbol{x_1}$=Sorghum $\boldsymbol{x_2}$=Chickpea $\boldsymbol{x_3}$= OFSP

Table 13 Functional property of each composite flours and individual flours

Run	Porridge component (%)			Functional property		
	Sorghum	Chickpea	OFSP	Bulk density (g/cm^3)	WAC (ml)	Viscosity index (g/sec)
1	40.0	35.0	25.0	0.81	1.00	1555.44
2	47.5	27.5	25.0	0.82	1.38	1060.41
3	47.5	27.5	25.0	0.82	1.38	1354.92
4	47.5	27.5	25.0	0.82	1.38	1500.17
5	55.0	20.0	25.0	0.83	1.50	1053.08
6	55.0	20.0	25.0	0.83	1.38	1338.08
7	52.5	25.0	22.5	0.82	1.25	1269.33
8	45.0	35.0	20.0	0.83	1.00	1645.78
9	50.0	30.0	20.0	0.82	1.13	1583.42
10	47.5	35.0	17.5	0.82	1.00	1943.26
11	47.5	35.0	17.5	0.83	1.00	1897.54
12	55.0	27.5	17.5	0.83	1.25	1626.06
13	55.0	27.5	17.5	0.84	1.13	1640.97
14	50.0	35.0	15.0	0.84	1.00	2025.57
15	55.0	30.0	15.0	0.84	1.13	1689.06
16	55.0	35.0	10.0	0.84	1.00	2322.89
	100	-	-	0.88	1.00	2615.07
	-	100		0.82	0.50	3710.24
	-	-	100	0.78	1.50	764.57
	Local sorghum			0.88	1.00	

Where: OFSP= Orange-fleshed sweet potato

Water absorption capacity

Water absorption capacity gives an indication of the amount of water available for gelatinization. The water absorption capacity (WAC) of the present study composite flour was varied between 1-1.5 mL (Table 13). Water absorption capacity was shown a highly significant difference at ($p<0.01$) in sorghum with chickpea interaction in linear model (Appendix Table 3).

The WAC was showed decreasing trend with the level of sorghum and chickpea flour increases. This result may be observed due to the low carbohydrate content of chickpea flour and processing effect (germination) of sorghum grain. Because germination was decreases the starch content of grain. As indicated by Lawal and Adebowale (2004) chemical composition that enhances the WAC of flours is carbohydrates, since this component contain hydrophilic parts, such as polar or charged side chains. According to Kaur and Sing (2005)**,** flours with high water absorption have more hydrophilic constituents, such as polysaccharides. Therefore, the higher water absorption capacity of OFSP flour than the other ingredient flours could be attributed to the presence of greater amounts of hydrophilic constituents.

The regression model for water absorption capacity;

$$y = -0.0215x_1 - 0.0856x_2 + 0.112C + 0.0024x_1x_2 - 4.797x_1x_3 - 9.7938x_2x_3 \ldots\ldots \text{Eq.27}$$

Where: y= Water absorption capacity $\boldsymbol{x_1}$=Sorghum $\boldsymbol{x_2}$=Chickpea $\boldsymbol{x_3}$= OFSP

Viscosity index

The viscosity index of porridge samples did not show significant difference. But the viscosity index of porridge samples was varied from 1053.08 to 2322.89 g/sec Table 13. Porridge prepared from lower chickpea flour proportion had the lowest viscosity compared to viscosity of porridge prepared from high chickpea flour proportion. As Figure 16b observed the viscosity of porridge was lower when the OFSP flour proportion increases in the composite flour in contrast when the chickpea flour increases the viscosity index was higher. This result observed due to the high water absorption capacity of chickpea during cooking.

The regression model viscosity index;

$y = 2034x_1 + 12186x_2 + 6165x_3 - 11164x_1x_2 - 8247x_1x_3 - 30842x_2x_3$.................Eq. 28

Where: y= Viscosity index; x_1=Sorghum x_2=Chickpea x_3= OFSP

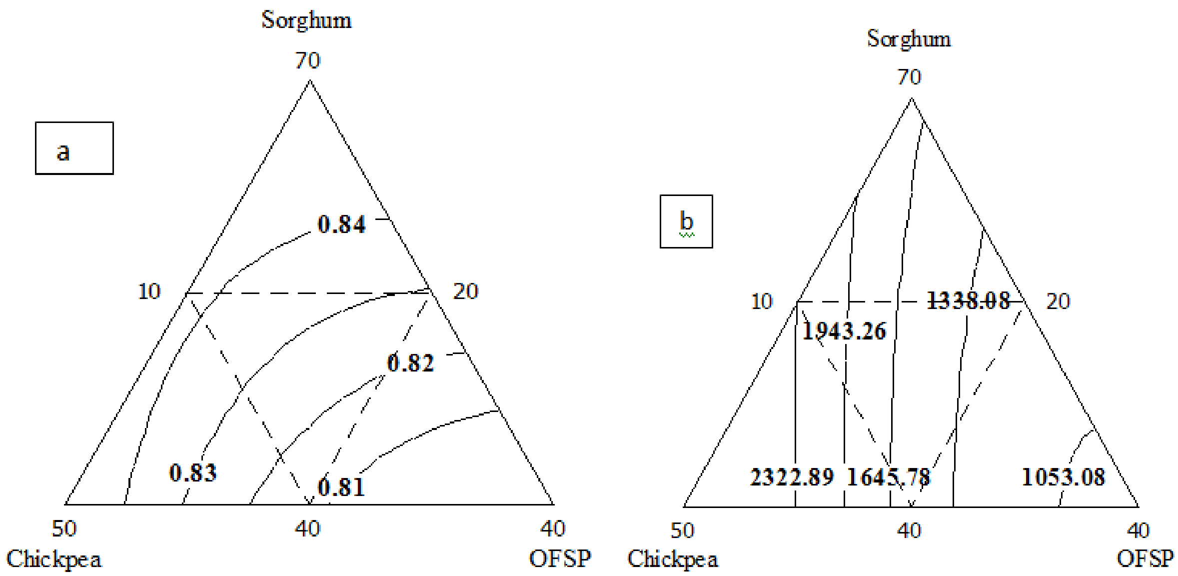


Figure 16 Effect of blending on (a) bulk density and (b) viscosity index of composite porridge in mixture contour graph

4.2.6. Sensory evaluation

The results of sensory evaluation were presented in (Table 14). The sensory analysis of variance result was summarized in the Appendix Table 4. Models for sensory evaluation were fitted indicated the diagnostic tools like normality plot of residuals indicated that the residuals of all the response variables are normally distributed. The lack of fit was highly significant (P<0.01) because of the magnitude of "pure error", which is the variability among the replications (among settings 2, 3, 4, and between settings 5, 6) were very low for all five responses. F for lack of fit is variability due to error minus that in the pure error divided by variability due to pure error. That is why the values of F were very high.

The data were presented on the mean consumer acceptance of the porridge prepared from sorghum, chickpea and OFSP composite flour for color, aroma, taste, mouth feel and overall acceptability. The mean scores indicated acceptability (degree of liking) of porridge for color, aroma, taste, mouth feel and overall acceptability with the numerical value that ranged between 2.88 to 4.82, 2.88 to 4.2, 2.76 to 4.44, 2.56 to 4.56 and 2.62 to 4.68 respectively.

Table 14 Sensory mean scores for samples (porridge) evaluated by untrained panels.

Run	Porridge components			Sensory attributes				
	Sorghum	Chickpea	OFSP	Color	Aroma	Taste	MF	OA
1	40.0	35.0	25.0	4.82	4.20	4.44	4.56	4.68
2	47.5	27.5	25.0	3.76	3.70	3.50	3.26	3.44
3	47.5	27.5	25.0	3.80	3.76	3.56	3.22	3.48
4	47.5	27.5	25.0	3.84	3.80	3.62	3.30	3.52
5	55.0	20.0	25.0	4.20	3.80	3.94	4.06	4.20
6	55.0	20.0	25.0	4.26	3.86	3.98	4.18	4.26
7	52.5	25.0	22.5	4.12	3.82	3.88	3.94	3.94
8	45.0	35.0	20.0	4.06	3.80	3.94	3.62	4.12
9	50.0	30.0	20.0	3.32	3.06	3.12	3.18	3.32
10	47.5	35.0	17.5	2.88	2.88	2.76	2.56	2.62
11	47.5	35.0	17.5	2.92	2.94	2.80	2.60	2.68
12	55.0	27.5	17.5	3.62	3.32	3.64	3.26	3.20
13	55.0	27.5	17.5	3.68	3.34	3.68	3.30	3.24
14	50.0	35.0	15.0	3.26	3.44	3.20	3.24	3.20
15	55.0	30.0	15.0	3.26	3.50	2.88	2.76	2.76
16	55.0	35.0	10.0	3.82	3.82	3.70	3.38	3.56

Where: OFSP = Orange-fleshed sweet potato MF = Mouth feel OA= Over all acceptability
The values indicated that 1. Dislike Very Much 2. Dislike 3. Neither Like or Dislike 4. Like 5. Like Very Much

Color

Vision plays a major role in sensory analysis and the appearance of food can have a major effect on its acceptability (Kikafunda *et al*., 2006). The color was showed a highly significant difference (P<0.01) sorghum with OFSP interaction in quadratic model; and significant difference (P< 0.01) sorghum with chickpea interaction. The composite flours porridge prepared from 40 % sorghum, 35 % chickpea and 25 % OFSP was the most preferred than others. The color of this product is light orange than the other due to the high amount of OFSP flour and low amount of sorghum flour.

The regression model for color;

$$\text{Color} = 37.2x_1 + 36.0x_2 + 80.0x_3 - 128.3x_1x_2 - 188.8x_1x_3 - 65.9x_2x_3 \ldots\ldots\ldots\ldots\text{Eq. 29}$$

$\boldsymbol{x_1}$=Sorghum $\boldsymbol{x_2}$=Chickpea $\boldsymbol{x_3}$= OFSP

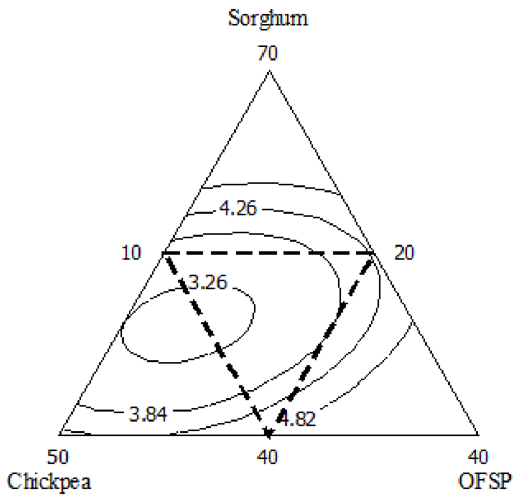


Figure 17 Effect of blending on color acceptability of porridge in mixture contour plot

Aroma

The aroma of the porridge samples showed significant difference (P<0.05) in quadratic model and in the interaction between chickpea and OFSP; and a highly significant difference (P<0.01) was observed between sorghum and OFSP interactions. The contour graph (Figure 18a) indicated that the acceptability of aroma was declined with the proportion of chickpea flour increases in the formulation. This result may be observed due to the beany flavor/aroma/ of chickpea flour. Similarly, Mc Watters (1978) indicated that the beany flavor in legumes flour could be reduced the acceptability of the product. As reported by Muhimbula *et al*. (2011) aroma is an integral part of taste and general acceptance of the food before it is put in the mouth.

The regression model for aroma;

$$\text{Aroma} = 20.9x_1 + 16.4x_2 + 79.9x_3 - 52.7x_1x_2 - 152.6x_1x_3 - 82.2x_2x_3 \ldots\ldots\ldots\ldots\text{Eq. 30}$$

$\boldsymbol{x_1}$=Sorghum $\boldsymbol{x_2}$=Chickpea $\boldsymbol{x_3}$= OFSP

Taste

The mean value of taste was found to be in the rage from 2.76 to 4.44 (Table 14). A significant difference ($P<0.05$) was observed in quadratic. The highest mean score for taste was obtained; when highest proportion of OFSP (25%) and lower proportion of sorghum (40%). The acceptability of the taste was increased with the level of OFSP proportion. This is due to the sweeter characteristics of OFSP flour. Similarly, Nandutu and Howell (2009) reported that sweet potato based complimentary food do not want additional sweetener ingredient. The score of mouth feel showed a significant difference ($P<0.05$) in quadratic model. Highly significant difference ($P<0.01$) was also observed in the interaction between sorghum with chickpea. The porridge samples prepared from (47.5% sorghum, 35% chickpea and 17.5% OFSP) and (55% sorghum, 30% chickpea and 15% OFSP) scored below the average level (neither like nor dislike) which are 2.56, 2.60 and 2.76 respectively which indicates those three products are disliked by the consumer. The other porridge sample scored greater than 3 (neither like nor dislike) this score indicated that most of the products are accepted by the consumer.

The regression model for taste;

Taste $= 34.1x_1 + 33.7x_2 + 65.7x_3 - 119.1x_1x_2 - 161.4x_1x_3 - 51.9x_2x_3$ ….................Eq. 31

$\boldsymbol{x_1}$=Sorghum $\boldsymbol{x_2}$=Chickpea $\boldsymbol{x_3}$= OFSP

Mouth feel

The results revealed that significant differences ($P > 0.05$) in sorghum with chickpea and sorghum with OFSP interaction were observed by untrained panelist between 16 porridge samples in terms of mouth feel and porridge sample prepared from (40% sorghum, 35% chickpea and 25% OFSP) and (55% sorghum, 20% chickpea and 25% OFSP) were highly liked as indicated by higher scores of 4.56 and 4.18 respectively. The mean score of formulations (47.5% sorghum, 35% chickpea and 17.5% OFSP) and (55% sorghum, 30% chickpea and 15% OFSP) was below the average mean less than 3 indicating that based on this test response variable these formulations were not liked by the panelists.

The regression model for mouth feel;

Mouth feel $= 39.9x_1 + 56.2x_2 + 63.4x_3 - 172.4x_1x_2 - 159.6x_1x_3 - 78.7x_2x_3$……………Eq. 32

$\boldsymbol{x_1}$=Sorghum $\boldsymbol{x_2}$=Chickpea $\boldsymbol{x_3}$= OFSP

Overall acceptability

The overall acceptability of porridge showed significant difference (p<0.05) in the quadratic model between sorghum with chickpea and sorghum with OFSP interactions. Among the sixteen runs, composite flours porridge sample prepared from (40% sorghum, 35% chickpea and 25%OFSP), (55% sorghum, 20% chickpea and 25%OFSP), and (45% sorghum, 35% chickpea and 20% OFSP) has most accepted with the mean score value (4.12 to 4.68) in their overall acceptability than the other porridge samples. The composite flours porridge samples prepared from (47.5% sorghum, 35% chickpea and 17.5% OFSP) and (55% sorghum, 30% chickpea and 15% OFSP) were disliked as compared to the others and their mean values were found to be 2.62, 2.68 and 2.76 respectively.

This result implied that, when sorghum and chickpea flour increased in composite flour the acceptability of the product decreased. This is because of the beany flavor of chickpea flour; and germination of sorghum flour. Shimelis *et al*. (2009) indicated that gruels prepared from germinated sorghum flour were slightly dark brown, had a bitter taste and a strong malt flavor. Hence, germination was improving the nutritional composition, but it affects slightly the acceptability of the product due to strong malt flavor. As shown in Figure 18d, the acceptability of the product increased in parallel with an increase in the proportion of OFSP flour. This acceptability may be depending on the sweeter characteristics of OFSP. Considering the nutritional benefits associated with the use of germinated cereals in the complementary food, there is a need to investigate the contribution of flavoring agents to improve the acceptability of the home-made complementary foods.

The regression model for color overall acceptability;

$OA = 35.9x_1 + 57.1x_2 + 74.5x_3 - 161.8x_1x_2 - 162.7x_1x_3 - 106.7x_2x_3$…………….……Eq. 33

Where: OA= Overall acceptability $\boldsymbol{x_1}$=Sorghum $\boldsymbol{x_2}$=Chickpea $\boldsymbol{x_3}$= OFSP

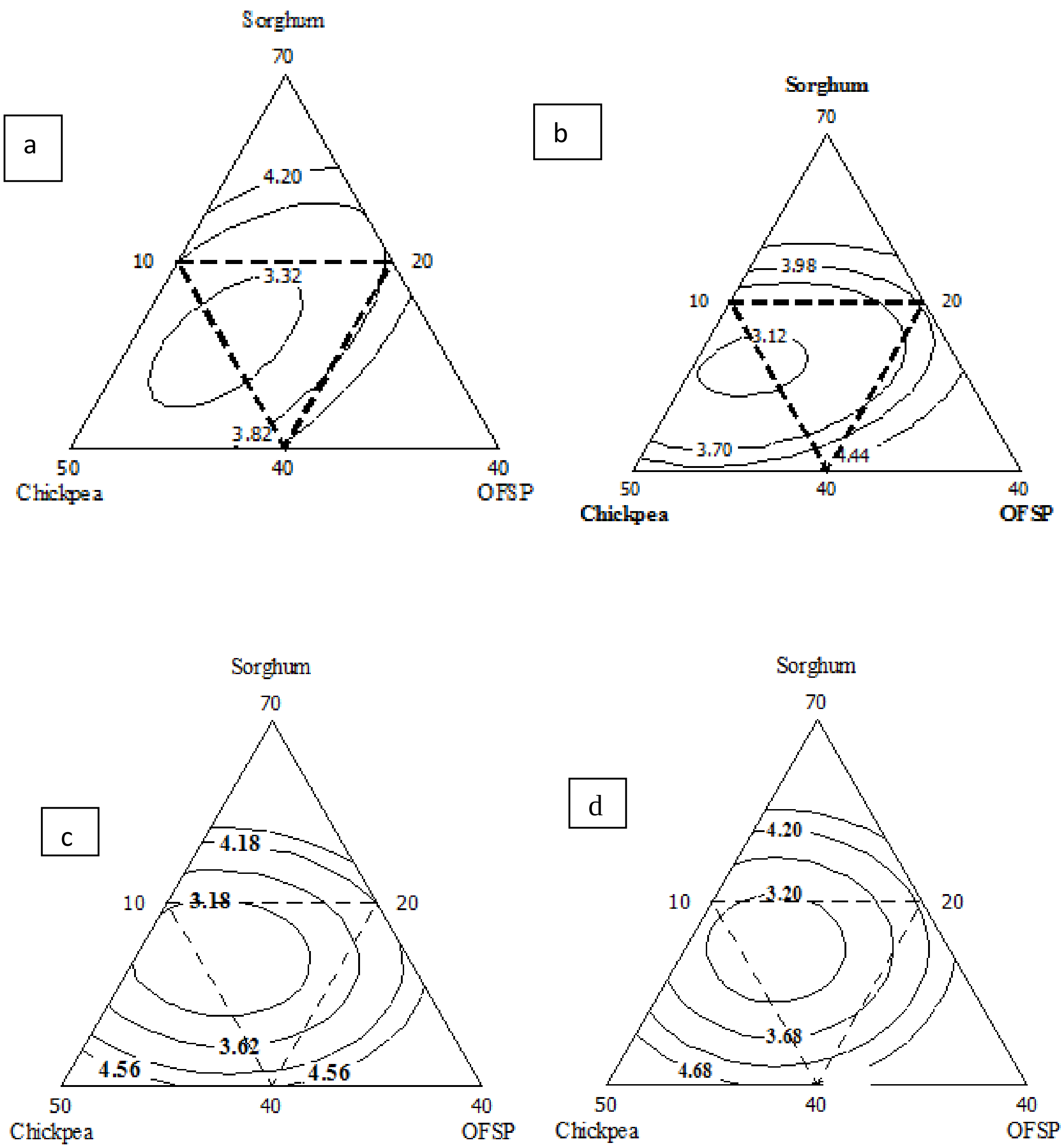


Figure 18 Effect of formulation on the aroma, taste, mouth feel and overall acceptability of composite flours porridge a, b, c and d respectively in mixture contour plot

4.2.7. Regions of optimum mixture composition

4.2.7.1. Chemical composition

The white area of Figure 19 indicates the optimum point of formulation to develop composite flours porridge with good chemical composition which can serve the expected purpose. The optimum point for protein, carbohydrate, calorie and β-carotene was varied between 11.91-13.73%, 72.21-74.76%, 380.37-393.08kcal/100g, 422.54-670.46μg/100g respectively. With respect to mineral content of the porridge samples, the optimum point for iron and calcium ranged between 4.28-7.65mg/100g and 65.18-71.54mg/100g respectively. The optimum point for the chemical composition of porridge samples was obtained through graphical optimization formulation, in which the proportion of sorghum ranged from 40-47.5%, chickpea 30-35% and OFSP 20-25% as indicated in Figure 19.

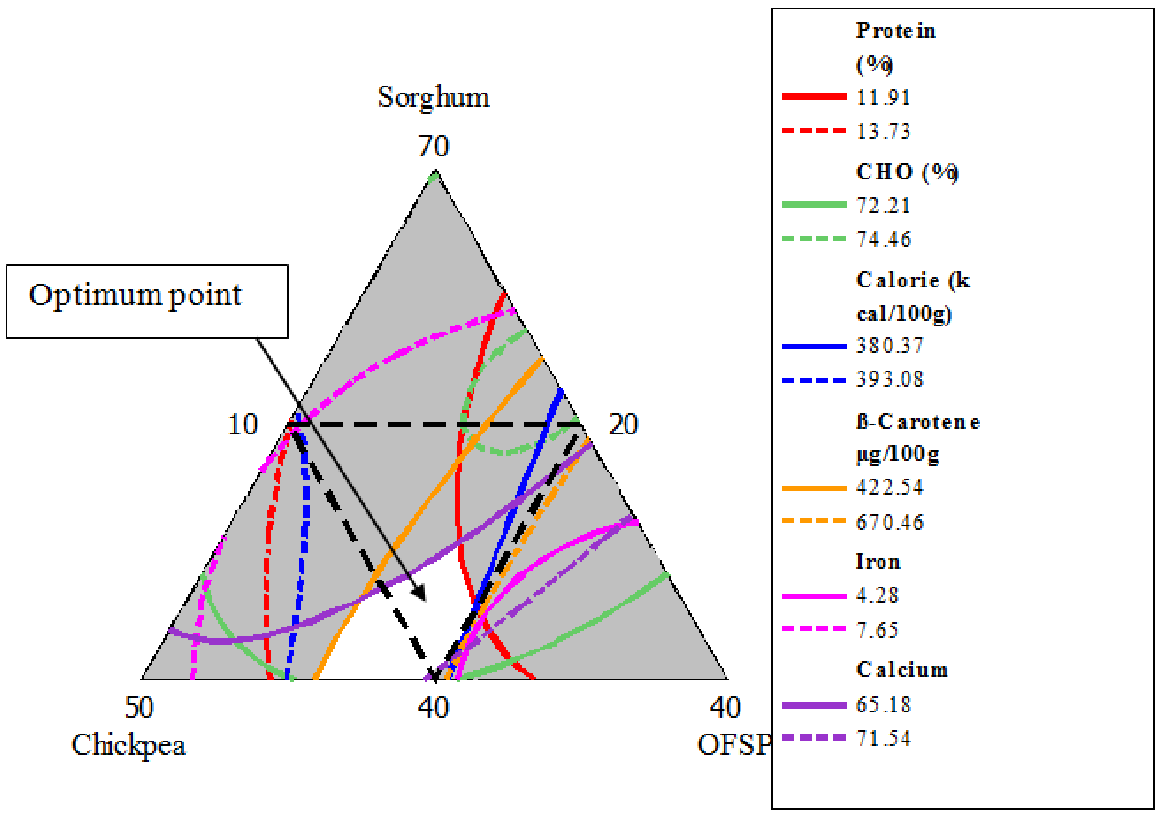


Figure 19 Overlaid contour plot of composite flours porridge chemical composition

4.2.7.2. Optimum point for sensory evaluation

The optimum formation should maximize consumer acceptance, it is impossible to develop a product with all five sensory qualities that would satisfy consumers in most applications (Moskowitz, 1994). Since, acceptability of the product by consumers is an essential parameter. To obtain the optimum region the ingredient formulation that would obtain optimum color, aroma, taste, mouth feel and overall acceptability for porridge. The optimum point for all sensory attributes was graphically presented below. The white region of Figure 20 shows the optimum sensory acceptability of the formula. The Point prediction shows that 40-55% sorghum, 20-35% chickpea and 22.5-25%. The optimal point for color, aroma, taste, mouthful and overall acceptability were found to be ranged from 3.8-4.82, 3.5-4.2, 3.64-4.44, 3.38-4.5 and the 3.52-4.68 respectively.

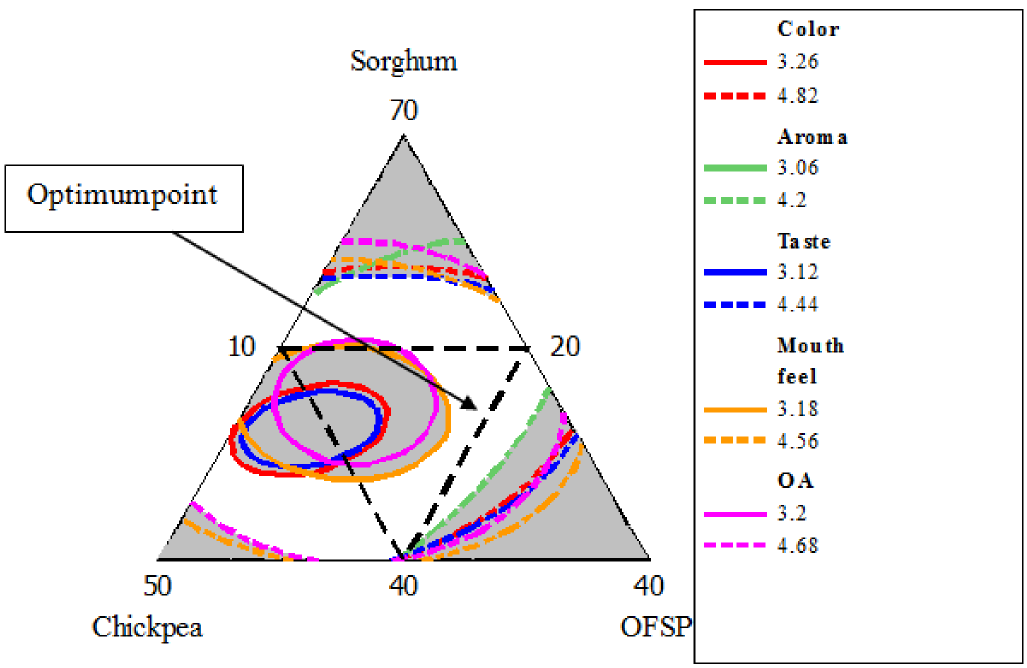


Figure 20 Optimum value of sensor evaluation of composite flours porridge indicated by overlaid contour graph

4.2.7.3. Optimal mixture composition of overall acceptability and chemical composition

The present work focused on determining the optimum blending ratio of each ingredient to produce porridge with the desirable nutrient compositions and sensory acceptability as compared to the porridge prepared from the local red sorghum flour as sole ingredient. The acceptability of the overall optimum value for protein, carbohydrate, calories, β-carotene, Iron, calcium and the overall acceptability varied between 11.91-13.73%, 4.47- 5.12%, 72.21-74.76%, 380.37-393.08kcal/100g, 422.54-670.46µg/100g, 4.28-7.65mg/100g, 65.18-71.54mg/100g and 3.52-4.68 respectively. The white region in the (Figure 21) indicates that an optimum combination of sorghum, chickpea and OFSP, which results in desirable attributes. The overall optimum point was found in sorghum 40-47.5%, chickpea 30-35% and OFSP 20-25%. Using this optimum amount of formulation can improved the protein (3.34 to 5.16%), fat (1.05-1.7%), energy (15.51 to 28.22 kcal), calcium (30.05 to 36.41 mg), and β-carotene (422.54-670.46µg/100 g) content of the complementary food prepared from red sorghum.

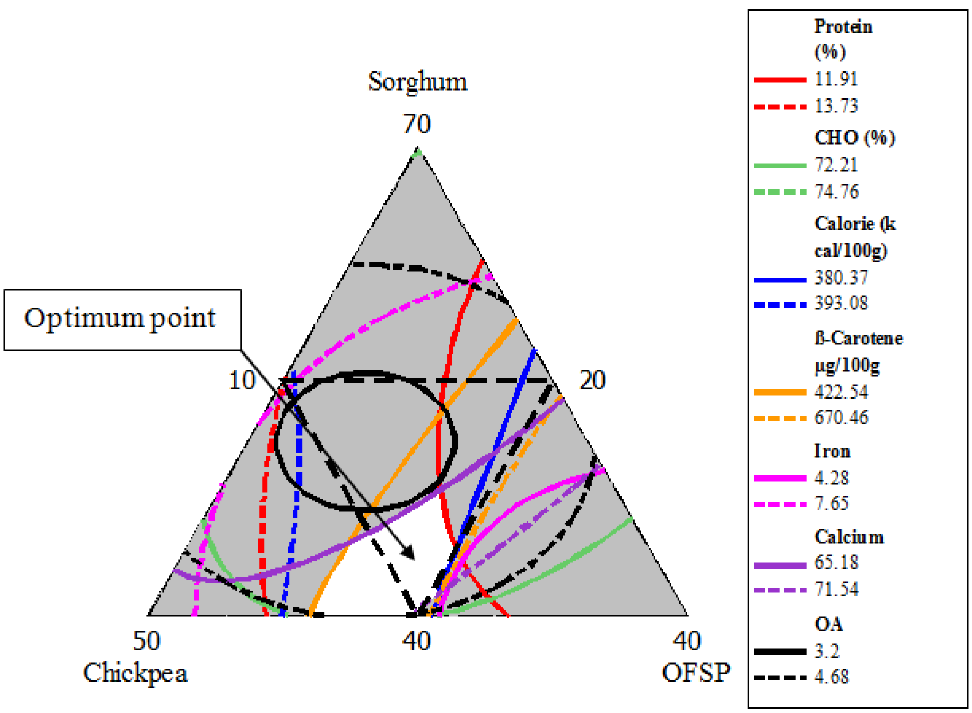


Figure 21 Overlaid contour plot of protein, carbohydrate, calorie, β-carotene, iron, calcium and overall acceptability of porridge

5. SUMMARY AND CONCLUSIONS

Cereals are used as a major source of nutrition for one third of the world's population especially in developing countries. Among these cereals, sorghum is one of the most important crops in its diversity of utilization contributing as a major source of calorie in human nutrition. In the present study, the field survey result revealed sorghum is one of the staple foods in the study area; 95.7% of the respondents in this area was consumed it alone or blending with other grains to improve the palatability of the food. From their experience around 37.2% of the respondent prepared complementary food from red sorghum alone and 56.04% of the respondents prepared by blending with other crops.

The result of this study indicated that, the protein, fat and energy content were significantly improved with increasing the proportion (20-35%) of the chickpea flour in the composite flour formula. β-carotene and calcium content of the product increased significantly with the increasing proportion of OFSP flour. The phytate concentration in the porridge was increased as the levels of sorghum flour increases to 55% while the tannin content was increased as the level of OFSP increase from 10 to 25%. The sensory acceptability of the porridge was from sixteen formulated complementary porridge run order 1 (sorghum 40%, chickpea 35% and OFSP 25%), run order 5 and 6(sorghum 55%, chickpea 20% and OFSP 25%) and run order 8 (sorghum 45%, chickpea 35% and OFSP 20%) scored better value in terms of overall acceptability. Formulation of a higher proportion of OFSP showed good sensory acceptability.

The optimum mixture proportion of sorghum, chickpea and OFSP flour induced significant improvement in the composite flours porridge nutritional quality and sensory attributes evaluated. The result revealed that sorghum, chickpea and OFSP crops have good potential for preparing vitamin A, protein and calorie rich complementary food. The optimum blending composite flours containing sorghum 40-47.5%, chickpea 30-35% and OFSP 20-25% was selected as a best formulation in terms of chemical composition and sensory qualities for protein 11.91-13.73%, carbohydrate 72.21-74.76%, calorie 380.37-393.08kcal/100g, β-carotene 422.54-670.46µg/100g, Iron 4.28-7.65mg/100g, calcium 65.18-71.54mg/100g. The overall acceptability of sensory attribute score in five hedonic scales was found to be in the ranged value from 3.52 to 4.68.

6. FUTURE LINE WORK

As future line work

- Further investigation should be done on the amino acid profile determination of the composite flour.

- Further study should be done on the microbial analysis and shelf life of the composite flour.

- Further study should be done on roasted chickpea to improve the beany flavor of blended product.

- Promotion of the complimentary food has to be done in Dawuro zone and all parts of Ethiopia.

7. REFERENCE

AACC, 2000. Approved methods of American Association of Cereal Chemists, 10th ed., vol. 11(Ed), St Paul M.N. USA.

Abara, A.E. 2003. Tannin content of *Dioscorea bulbufera*. *J. of Chem. Soc.Nigeria*, **28**:55 56.

ACC/SCN, 2000. Fourth Report on the World Nutrition Situation. Geneva. Standing Committee on Nutrition, U.N.

Achi, O.K. 2005. The potential for upgrading traditional fermented foods through biotechnology. *African J. of Biotech*.**,** **4**:375-380.

Adebayo**-**Oyetoro, O.P. O.O. Olatido, E.A. Ogundipe and C.G. Isaiah, 2012. Production and quality evaluation of Complementary food formulated from fermented Sorghum, walnut and ginger. *J. Appl. Bio. Sci.* **54**:3901-3910.

Adeleke, R.O. and J.O Odedeji, 2010. Functional properties of wheat and sweet potato flour blends. *Pakistan J. of Nut*., **9(6):**535-538.

Adenuga, W. 2010. Nutritional and sensory profiles of sweet potato based infant weaning food fortified with cowpea and peanut. *J. Food Techno*., **8 (5):**223-228.

Adeparusi, E.O. 2001. Effect of processing on the nutrients and anti- nutrients of lima bean (phaseolus lunatus L.) flour. *Nahrung/Food*., **4**:94-96.

Akaninwor, J.O. and Okechukwu, P.N. 2004. Biochemistry. **16:**15-21.

Akubor, P.I. and M.U. Ukwuru, 2003. Functional properties and biscuit making potential of soybean and cassava flour blends. *Plt Foods for Hum. Nut.* **58:** 1–12.

Akubor, P.I., D. Yusuf and J.E. Oviegunam, 2013. Proximate composition and some functional properties of flour from the kernel of African star apple (chrysophyllual albidum). *Inter. J. of Agr. Policy and Res*. **(3)**:032-066.

Alajaji, S.A. and A.H. El-adawy, 2006. Nutritional composition of chickpea (*Cicer arietinum* L.) as affected by microwave cooking and other traditional cooking methods. *J. Food Comp. Anal*., **19**:806–812.

Alemu, K.M. 2009. The effect of natural fermentation on some antinutritional factors, minerals, proximate composition and sensory characteristics in sorghum based weaning foods. M.Sc thesis, Addis Ababa University, Ethiopia.

Almeida-Dominguez, H.D., S.O. Serna-Saldivar M.H., Gomez and L.W. Rooney, 1993. Production and nutritional value of weaning foods from mixtures of pearl millet and cowpeas. *Cereal Chem.,* **70(1):**14-18.

Alonso, R., E. Orue and F. Marzo, 1998. Effect of extrusion and conventional processing methods on protein and anti-nutritional factor contents in pea seeds. *J. of Food Chem*. **63**:505–512.

Amagloh F.K., J.L. Weber, L. Brough, A., Hardacre, A.N. Mutukumira and J. Coad, 2012. Complementary food blends and malnutrition among infants in Ghana: A review and a proposed solution. *Sci. Res. and Essays*., **7(9)**:972-988.

Amankwah, E.A., J. R. Barimah, L.O. Acheampong, and C.O. Nnaji, 2009. Effect of Fermentation and Malting on the Viscosity of Maize-Soyabean Weaning Blends. *Pakistan. J. of Nut.* **8(10**):1671-1675.

Ameny, M.A. and P.W. Wilson, 1997. Relationship between Hunter color values and β-carotene contents in white fleshed African sweet potatoes (Ipomea batatas Lam). *J. of Sci. of Food and Agr*., **73**:301-306.

Amlan k.P., 2012. Dietary phytochemicals and microbes. West Bengal University of Animal and fishery sciences. Belgachia, Kolkata, India.pp:354-355

Anglani, C. 1998. Sorghum for human food: a review. *Plt Foods Hum. Nut*., **52**:85-89.

Anigo, K.M., D.A. Ameh, S. Ibrahim and S.S. Danbauchi, 2009. Nutrient composition of commonly used complementary foods in North Western Nigeria. *African J. Biotech*., **8(17**):4211-4216.

AOAC., 2000. Association of Official Analytical Chemists. Official methods of Analysis 17th ed. of AOAC International. Washington, DC, USA.

AOAC., 2005. Association of Official Analytical Chemists. Official methods of Analysis 18th ed. of AOAC International. Washington, DC, USA.

Asante, S.A., 1995. Sorghum quality and utilization. *African Crop Sci. J*., **3(2):** 231-240.

Asfaw, A., 2007. The role of introduced sorghum and millets in Ethiopian agriculture, SAT Eth. J**. 3.**

Asha, V.B., K. Geetha, K. Sheela and G.N. Dhanapal, 2005. Nutritional composition of Sorghum and Mouth Bean Incorporated Traditional Recipes. *J. Hum. Ecol*., **17(3)**:201-203.

Ayana, A., 2001**.** Genetic diversity in sorghum (*Sorghum bicolor* (L.) Moench) germplasm from Ethiopia and Eritrea. PhD Thesis, Addis Ababa University, Addis Ababa, Ethiopia.

Aziah, N.A., N. Mohamad and L.H. Ho, 2012. Physicochemical and organoleptic properties of cookies incorporated with legume flour. *Inter. Food Res. J*., **19**(**4**):1539-1543.

Bardocz, S., E. Gelencer and A. Pusztai, 1996. Effects of anti-nutrients on the nutritional value of legume diets. **1.**

Barker J.P., 2001. The malnourished baby and infant. *British Medical Bull.*, **60**:69–88.

Bechoff, A., 2010. Investigating carotenoid loss after drying and storage of orange fleshed sweet potato. PhD dissertation. Natural Resources Institute, University of Green wich, UK.

Bekele, S. and T. Hailemariam, 2007. Structure and functioning of chickpea markets in Ethiopia Evidence based on analyses of value chain linking small holders and markets. Improving productivity and market success (IPMS) of Ethiopian farmer's project. Intern. Livestock res. Inst. **6**.

Beta, T., L.W. Rooney and R.D. Waniska, 1995. Malting characteristics of sorghum cultivars. *Cereal Chem*., **72**:533-538.

Beta, T., L.W. Rooney, L. Marovatsanga and J.R Taylor, 1999. Phenolic compounds and kernel characteristics of Zimbabwean sorghum. *J. of the Sci. of Food and Agr*., **79**:1003-1010.

Beuchat, L.R., 1977. Functional and Electrophoretic characterstics of succinylated peanut flour protein. *J. Agr. Food. Chem*., **25**:258-261.

Binita, R. and N. Khetarpaul, 1997. Probiotic fermentation: Effect on anti-nutrients and digestibility of starch and protein of indigenous developed food mixture. *J. of Nut. and Health*. **18**:139-147.

Brunken, G.S., S.M. Silva, G.V. França, M.M. Escuder and S.I. Venancio, 2006. Risk factors for early interruption of exclusive breastfeeding and late introduction of complementary foods among infants in mid western Brazil. *J. Pediatr Rio,* **82(6)**:445-51.

Burbano, C., M. Muzquiz, A. Osagie, G. Ayet and C. Cuadrado, 1995. Determination of phytate and lower inositol phosphates in Spanish legumes by HPLC methodology. *Food Chem.* 62, 321–326.

Cameron, M. and G. Hofvander, 1983. Manual feeding infants and young children, 3rd edition, PP.116-131.

Chavan, J.K. and S.S. Kadam, 1989. Nutritional improvement of cereals by sprouting. *Critical Review. Food Sci. Nut.* **28**:401-437.

Clifford, M.N. and Scalbert, A., 2000. Ellagitannins-nature, occurrence and dietary burden. *J. Sci. Food Agr.*, **80**:1118-1125.

Cochran, W.G., 1977. Sampling techniques (3rd ed.). New York: John Wiley & Sons.

CSA., 2006. Agricultural sample survey of livestock and livestock characteristics of 2006/07. Statistical Bulletin 388. Volume II, Addis Ababa,Ethiopia.

CSA., 2013. Agricultural Sample Survey of Area and production of Major Crops of 2012/13 Statistical bulletin 532. Volume I, Addis Ababa,Ethiopia.

Daelmans, B., J., Martines, R., Saadeh, 2003. Conclusions of the Global Consultation on Complementary Feeding. *Food Nu. Bull*.**24**:126-9.

Daelmans, B. and R. Saadeh, 2003. Global initiatives to improve complementary feeding. In SCN Newsletter: Meeting the challenge to improve complementary feeding. United Nations System Standing Committee on Nutrition. Moreira,A.D. Ed. Lavenhem Press, UK pp. 10-17.

Dejene D., 2010. Study on the Effect of Traditional Processing on Proximate Composition and Bio-availability of Minerals in Chickpea (*Cicer arietinum*) grown in Ethiopia. MSc Thesis, Addis Ababa University, Addis Ababa.80pp.

Deshpande, S.S., S.k. Sathe, D.k. Salunkhe and D.P. Cornforth, 1982. Effect of de-hulling on phytic acid, polyphenols, and enzyme inhibitors of dry beans (Phaseolus vulgaris L.). *J. of Food Sci.*, **47**:1846-1850.

Dewar, J., 2003. Influence of malting on sorghum protein quality. http://www.afripro.org.uk/papers/Paper18Dewar.pdf cited 20/10/2012.

Dewey, K.G. and K.H. Brown, 2003. Update on technical issues concerning complementary feeding of young children in developing countries and implications for intervention programs. *Food Nut. Bull*. **24(1)**:5–28.

Dicko, M.H., 2005. Endogenous phenolics and starch modifying enzymes as determinants of sorghum for food use in Burkina Faso. *PhD Thesis: Wageningen University, The Netherlands.*

Dicko, M.H., H. Gruppen, A.S. Traore, A.G. Voragen and V.W. Berkel, 2006. Sorghum grain as human food in Africa: relevance of content of starch and amylase activities. *Afr. J. Biotech*., **5** (**5**):384-395.

Egli, I.M., 2001. Traditional Food Processing Methods to Increase Mineral Bioavailability from Cereal and Legume Based Weaning Foods. A PhD dissertation, Swiss Federal Institute of Technology Zurich.

El-Adawy, T.A., 2002. Nutritional Composition and Antinutritional Factors of Chickpeas (*Cicer arietinum* L.) Undergoing Different Cooking Methods and Germination. *Plt Food for Hum. Nut*., **57:**83–97.

Elemo, G.N., B.O. Elemo and J.N. Okafor, 2011. Preparation and nutritional composition of a weaning food formulation from germinated sorghum (sorghum bicolor) and steamed cooked cowpea (vigna unquiculata walp.) *American. J. of Food Techno.*, **6**(**5**):413-412.

Emami, S. and L.G. Tabil, 2002. Processing of Starch-Rich and Protein Rich Fractions from Chickpeas A review.An ASAE/CSAE. Meeting presentation, Paper No: MBSK 02-212.

Emmanbux, M.N., J.R. Taylor, 2003. Sorghum kafirin interaction with various phenolic compounds. *J. of Sci. Food and Agr.*,**83**: 402-407.

Ermias Shonga, Mesele Gemu, Tesfaye Tadesse and Elias Urage, 2013. Review of Entomological Research on Sweet Potato in Ethiopia. *Disc. J.of Agr. and Food Sci.* **1(5):**83-92.

Eshetu G. and E. Dula, 2013. Household structure and children's nutritional status in Ethiopia. **69(2)**:113-130.

Esmat, A., A. Abou, I.M. Helmy and G.F. Bareh, 2010. Nutritional Evaluation and Functional Properties of Chickpea (Cicer arietinum L.) Flour and the Improvement of Spaghetti Produced from its. *J. of American Sci.*; **6(10):**1055-1072.

Esther, E.N. and O.A. Ignitiatus, 2010. Effect of processing on the Mineral Composition and Anti nutritional factors of Orange-Fleshed Sweet potato (*Ipomoea batatas L. Lam*) Flours. *EJEAF Chem.*, **9(6):**1000-1005.

FAO, 1999. Improvement and production of maize, sorghum and millet FAO plant production and protection paper 24, pp: 243

FAO, 2001. FAO's State of Food Insecurity. Rome, Italy.

FAO, 2008. Food and Agricultural Organization Statistical Database. Rome: FAO (Food and Agricultural Organization at www.faostat.org).

FAO,1995. Sorghum and Millets in Human Nutrition. FAO and Nutrition series No 27.Food and Agricultural Organization of the united Nations: Rome.

FAO/ICRISAT.,1996. The world sorghum and millet economics: facts, trends and outlook. Food and agriculture Organization (FAO) and International crops Research Institute for the semi-Arid Tropics (ICRISAT): Rome, Italy/ Patoncheru, India.

FAOSTAT, 2008. Food Agriculture organization statistical database. http://faostat. Fao.org.

FAOSTAT, 2012. FAO Statistics Division 2014/19 Accessed date on February 2014.

Food and Nutrition Board, 2005. Dietary Reference Intake for Energy, Carbohydrate, Fiber, Fat, Fatty Acids, Cholesterol, Protein and Amino Acids. Institute of Medicine of the National Academies press, Washington DC.

Frossard, E., M. Bucher, F. Maechler, A. Mozafar and R. Hurrell, 2000. Potential for increasing the content and bioavailability of Fe, Zn and Ca in plants for human nutrition. *J.of the Sci. of Food and Agr*., **80**:861-879.

Garcia-Lopez, S., J.W. Erdman and A.R. Sherman, 1990. Iron retention by rats from casein-legume test meals: effect of tannin level and previous diet. *J. of Nut.* **120**: 760–766.

Gebremedihn, K., A. Kebede, M. Afework and P. Singh, 2013. Nutritional Analysis of Vitamin A Enriched Bread from Orange Flesh Sweet Potato and Locally Available Wheat Flours at Samre Woreda, Northern Ethiopia. *Curr. Res. in Nut. and Food Sci*., **1(1):** 49-57.

Gilani, G.S., K.A. Cockell, and E. Sepehr, 2005. Effects of Antinutritional factors on protein digestibility and amino acid available in foods. *J. of AOAC Inter.* **88(3)**:967-987.

Glew, R.H, D.J. Vanderjagt, C. Lockett, L.E. Grivetti, G.C. Smith, A. Pastuszyn and M. Millson, 1997. Amino acid, fatty acid, and mineral composition of 24 indigenous plants of Burkina Faso. *J. Food Comp. Anal.* **10**:205-217.

Gordon, M.S., 1993. Simulation tools for the thermal processing of foods. *Food Techno. Info*. **8**: 100-102.

Guria P., 2006. Physico-Chemical Properties, Nutrition quality and Value Addition To quality Protein Maize (Zea Mays L.) A Thesis for Master of Home Science Submitted to the Department of Food Science and Nutrition, University of Agricultural Sciences, Dharwad.

Hagerman, A.E. and D.M. Carlson, 1998. Biological Responses to Tannins and other polyphenols. *Res. Dev. Agr. Food Chem*. **2**:689-704.

Haidar, J., G. Abate, W. Kogi-Makau and P. Sorensen, 2005. Risk factors for child under-nutrition with a human rights edge in rural villages of North Wollo, Ethiopia. *East Afr. Med. J*, **82(12):**625-630.

Haslam, E., 1989. Vegetable tannins. In: Conn EE. The biochemistry of plants, Academic Press, New York, **7**:527-544.

Hefnawy, T.M., G.A. El-shourbagy and M.F. Ramodan., 2012. Impact of adding chickpea (Cicer arietinum L.) flour to wheat flour on the rheological properties of toast bread. *Inter. Food Res. J.* **19(2):**521-525.

Helland, M.H., T. Wicklund, and J.A. Narvhus, 2002. Effect of germination time on *alpha-amylase* production and viscosity of maize porridge. *Food Res. Inter*., **35**:315-321.

Hussain, I., M.B. Uddin, and M.G. Aziz, 2011. Optimization of anti-nutritional factors from germinated wheat and mungbean by Response Surface Methodology. *Inter. Food Res. J.*, **18(3)**: 957-963.

Idris, W.H., S.M. Abdel, H.B. Rahman, El Maki, E.E. Babiker and A.H. El Tinay, 2007. Effect of malt pretreatment on HCl-extractability of calcium, phosphorus and iron of sorghum (*sorghum biocolor*) cultivars. *Inter. J. Food Sci. Techno*., **42**:194-199.

Ijarotimi, O.S and O.A. Ayantokun, 2006. Nutritional composition, sensory and Biological Evaluation of a potential weaning diet from low cost food material (sorghum bicolor and Cajanus cajan). *J. of Food Techno.* **4(3):**178-184.

Ikujenlola, V.A. and J.B. Fashakin, 2005. The Physico-Chemical Proiperties of a Complementary diet prepared from vegetable proteins. *J. Food Agr. Envir.*, **3**(**3**):23-26.

Iqbal, A. N., Ateeq, I.A. Khalil, S. Perveen, and S. Saleemullah, 2006. Physicochemical characteristics and amino acid profile of chickpea cultivars grown in Pakistan. *J. Food service*., **17**: 94-101.

Isabel, G. and V.G. Garmen, 2003. Chickpea flour ingredient slows glycemic response to pasta in healthy volunteers. *Food Chem.*, **81**:511-515.

Jaarsveld, P.J., M. Faber, S.A. Tanumihrd, P.L. Nestel and C.J. Benade, 2005. Beta carotene rich Orange fleshed sweet potato improves the vitamin A status of primary school children assessed with the modified relative dose-response test. *The American. J. of Clin. Nut*., **81**:1080-1087.

Jaarsveld, P.J., D.W. Marais, E. Harmse, P. Nestel and A.D. Rodriguez, 2006. Retention of β-carotene in boiled, meshed orange fleshed sweet potato. *J. of Food comp. and Anl*., **19**:321-329.

Jansman, A.F., A.A. Frohlich, and R.R. Marquardt, 1994. Production of proline-rich proteins by the parotid glands of rats is enhanced by feeding diets containing tannins from faba beans (Vicia faba L.). *J. Nut.*, **124**:249–258.

Kanu, P.J., Z., Kerui, J.B. Kanu and Z. Huiming, 2009. Effects of Enzymatic Hydrolysis with Alcalase on the Functional Properties of Protein Hydrolysis from Defatted Sesame Flour. *J Food Sci. Techno.*, **3**:196- 201.

Kapinga R, J. Ndunguru, G. Mulokozi, S. Tumwegamire, 2009. Impact of common sweet potato viruses on total carotenoids and root yields of an orange-fleshed sweet potato in Tanzania. *Sci. Hort.* **122**:1–5.

Kaur, M. and N. Singh, 2005. Studies on functional, thermal and pasting properties of flours from different chickpea (*Cicer arietinum* L.) cultivars. *Food Chem*., **91**:403-411.

Khanbabaee, k. and T.V. Ree, 2001. Tannins: classification and definition. *Nat. Prod. Rep.*, **18**:641-649.

Khertapaul, N. and A. Sharme, 1997. Effect of fermentation with wey on the hcl extractability of minerals from rice-dehulled black gram blends. *J. of Agr. and Food Chem*., **45**:2258-2261.

Kikafunda, J.K., L. Abenakyo and F.B. Lukwago, 2006. Nutritional and sensory properties of high energy/nutrient dense composite flour porridges from germinated maize and roasted beans for child-weaning in developing countries: a case for Uganda. *Ecol. Food Nut*., **45**:279–294.

Kinsella J.E., 1976. Functional properties of proteins in foods. A Survey. *Critical Review in Food Sci. and Nut.,* **7**:219-232.

Kinsella, J.E., 1987. Functional properties of protein: Possible relationship between structure and function in foods. *Food chem*., **7(2)**:275-288.

Kumar, R., 1992. Anti-nutritional factors, the potential risks of toxicity and methods to alleviate them. Proceedings of the FAO Expert Consultation held at the Malaysian Agricultural Research and Development Institute (MARDI) in Kuala Lumpur, Malaysia, 14-18 October, 1991. Andrew Speedy and Pierre-Luc Puglise (eds).

Kumar, R. and M. Singh, 1984. Tannins: their adverse role in ruminant nutrition. *J. of Agr. and food Chem*., **32**:447-453.

Kumar, V., A.V. Elangovan and A.B. Mandal, 2005. Utilization of reconstituted high-tannin sorghum in the diets of broiler Chickens. *Asian-Aust. J. Anim. Sci*. **18(4)**:538-544.

Lartey, A., A., Manu, K.H., Brown, J.M. Peerson, and K.G. Dewey, 1999. A randomized, community based trial of the effects of improved, centrally processed complementary foods on growth and micronutrient status of Ghanaian infants from 6 to 12 months of age. *American. J. Clin. Nut*., **70**(**3**):391-404.

Lawal, O.S. and K.O. Adebowale, 2004. Effect of acetylation and succinylation on solubility profile, water absorption capacity, oil absorption capacity and emulsifying properties of muncuna bean (Mucuna pruiens) protein concentrate. *Nahrung/Food*, **48**(**2**):129-136.

Lee, Y.R., J.Y. Kim, K.S. Woo, I.G. Hwang, K.H. Kim, and H.S. Jeong, 2007. Changes in the chemical and functional components of Korean rough rice before and after germination. *Food Sci. Biotech.*, **16**(**6**):1006-1010.

Leighton, C.S., 2007. Nutrient and sensory quality of Orange fleshed sweet potato. MSc. thesis in consumer science, University of Pretoria, South Africa.

Livingstone, A.S., J.J. Feng, and N.G. Malleshi, 1993. Development and nutritional quality evaluation of weaning foods based on malted, popped and dried wheat and chickpea. *Inter. J. Food Sci. Techno.*, **28**:35-43.

Lorenz, A.J., M. P. Scott and K. R. Lamkey, 2007. Quantitative determination of phytate and inorganic phosphorus for maize breeding. *Crop Sci. Society of America.* **47:**600-604.

Low, J., K. Peter, G. Simon, A. Mary, M. Vital and K. Jackson, 1997. Combating vitamin A deficiency through the use of sweet potato results from phase I of an action research project in south Nyanza, Kenya. International potato center in collaboration with the Kenya agricultural research Institute Lima, peru.

Low, J.w., M. Arimond, N. Osman, B. Cunguara, F. Zano and D. Tschirley, 2007. A food based Approach introducing orange fleshed sweet potatoes increased vitamin A intake and serum Retinol concentrations in young children in Rural Mozambique. *J. of Nut*., **137(5)**:1320-1327.

Mahajan A. and S. Dua, 2002. Salts and pH induced changes in functional properties of amaranth (Amatanthus tricolor L.) seed meal. *Cereal Chem.***79**:834–837.

Mahgoub, 1999. Production and evaluation of weaning foods based on sorghum and legumes. *Plt foods for Hum. Nut*. **54**:29-42.

Maiti, R. and P. Wesche-Ebeling, 2001. In R. Maiti and P. Wesche-Ebeling (Eds.), Advances In chickpea science (pp. 1). Science Publishers Inc.

Makinde, F.M. and A.T. Ladipo, 2012. Physico- chemical and microbial quality of sorghum based complementary food enriched with soybean (*Glycine max*) and sesame (S*esamum indicum*). *J. of Food Techno*., **10(2**):46-49.

Makokha, A.O., R.K. Oniang'o, S.M. Njoroge and O.K. Kamar, 2002. Effect of traditional fermentation and malting on phytic acid and mineral availability from sorghum (Sorghum bicolor) and finger millet (Eleusine coracana) grain varieties grown in Kenya. *Food Nut. Bull.,* **23**:241-5.

Maleki, S., 2001. The big eight food allergens, *Dietitian's Edge*, **2**:57–60.

Malomo, S.A., A.F. Eleyinmi and J.B. Fashakin, 2011. Chemical composition, rheological properties and bread making potentials of composite flours from breadfruit, breadnut and wheat. *African J. of Food Sci.*, **5(7):** 400 – 410.

Mamary, A., M. Hobori, M.A. Aghbari and A. Obeidi, 2002. *In vivo* effects of dietary sorghum tannins on rabbit digestive enzymes and mineral absorption. *Nut. Res*. **21**:1393-1401.

Masood S. B. and B. Rizwana, 2010. Nutritional and Functional Properties of Some promising Legumes Protein Isolates. *Pakistan J. of Nut.* **9 (4)**:373-379.

Maxson, E.D. and L.W. Rooney, 1972. Two methods of tannin analysis for *sorghum bicolor* (L.) Moench grain. *Crop sci*., **12**:253.

Mbwaga, 2007. Quality and yield stability of orange-fleshed sweet potato (Ipomoea batatas (L.) Lam.) varieties in different Agro-ecologies. M.Sc. thesis presented in school of agricultural sciences. Zambia University.

McWatters, K. H., 1978. Cookie baking properties of defatted peanut, soybean and field pea flours. *Cereal Chem.*, **55**:853-863.

Melaku, U., C.E. West and F. Habtamu, 2005. Content of zinc, iron, calcium and their absorption inhibitors in foods commonly consumed in Ethiopia. *J. Food Comp. Anal*., **18**:803–817.

Menale, K., S. Bekele, A. Solomon, A. Tsedeke, M. Geoffrey, F. Setotaw, E. Million and A. Kebebew, 2009. Current Situation and Future Outlooks of the Chickpea sub-sector in Ethiopia; Ethiopian Institute of Agricultural Research (EIAR), Debre Zeit Agricultural Research Center, Debre Zeit , Ethiopia.

Metwalli, O., M.Y. Sahar, T. Al-Okbi and E. Hamed, 2011. Chemical, biological and organoleptic evaluation of newly formulated therapeutic diets for protein calorie malnutrition. *Medical J. of Islamic World Acad. of Sci.*, **19(2)**: 67-74.

Mingshu, L., Y. Kai, H. Qiang and J. Dongying, 2006. Biodegradation of gallatannins and -ellagitannins. *J. Basic Microbio.*, **46**:68-84.

Mitra, S., 2012. Nutritional Status of Orange-Fleshed Sweet Potatoes in Alleviating Vitamin A Malnutrition through a Food-Based Approach. *J Nut. Food Sci.*, **2**:160.

Mittal, R., H.P., Nagi, P. Sharma and S. Sharma, 2012. Effect of Processing on Chemical Composition and Anti-nutritional Factors in Chickpea Flour. *J. of Food Sci. and Eng.* **2**:180-186.

Mohamed, M.E., B.H Amro, A.S. Mashier and E.B. Elfadil, 2007. Effect of Processing Followed by Fermentation on Antinutritional Factors Content of Pearl Millet (Pennisetum glaucum L.) Cultivars. *Pakistan. J. Nut.*, **6**:463-467.

Mohamed, N., A.A., Isam, A.M., Babiker, E.E. and A.Y. Abu El Gasim, 2010. Investigations on winter season Sudanese sorghum cultivars: Effect of sprouting on the nutritional value. *Inter. J. Food Sci. Techno.* **45**:884–890.

Mohammed, A.N., A. Isam, M. Ahmed and. E.E. Babiker, 2011. Nutritional Evaluation of Sorghum Flour (*Sorghum bicolor L. Moench)* During Processing of *Injera. World Acad. of Sci., Eng. and Techno.,* **51.**72-76.

Mohiedeen, I.E., Abdullahi, H.E., Abd Elmoneim, O.E., Babiker, E.E. and Mallasy, L.O., 2010. Effect of fermentation and cooking on protein quality of maize (*Zea Mays Linnaus*) cultivars. *Inter. J. Food Sci. Techno*., **45**:1284-1290.

Mosha T.C.E, H.S. Laswai, and I. Tetens, 2000. Nutritional composition and micronutrient status of homemade and commercial complementary foods consumed in Tanzania. *Plt Foods for Hum. Nut.*. **55**:185-205.

Mosha, C.E and M.M. Vicent, 2005. Nutritional Quality, Storage Stability And Acceptability of Home-Processed Ready-To-Eat Composite Foods for Rehabilitating Undernourished Preschool Children In Low-Income Countries. *J. of Food Proc. and Preserv.* **29**:331–356.

Moskowitz, H.R., 1994. Product Optimization: Approaches and Applications. Blackie Academic & Professional, London, U.K. pp 97 – 136.

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

Muzquiz, M. and J.A. Wood, 2007. Anti-nutritional factors. In chickpea. Inter. *J. of Food Sci. and Nut.*, **55:**143-158.

Nalle, C.L., 2009. Nutritional evaluation of grain legumes for poultry. A thesis presented in partial fulfillment of the requirements for the degree of Doctor of philosophy in poultry nutrition. At Massey University, Palmerson North, New Zealand.

Nandutu, A., and N. Howell, 2009. Nutritional and rheological properties of sweet potato based infant food and its preservation using antioxidants. *African. J. Food Agr. Nut.. Dev.* **9(4)**:1076- 1090.

Nnam, 2000. Chemical, sensory and rheological properties of porridges from processed sorghum (*Sorghum bicolor*), bambara groundnut (*Vigna subterranea* L. Verdc) and sweet potato (*Ipomoea batatas*) flours. *Plt Foods for Hum. Nut.* **56:** 251–264.

Oboh, H.A., M. Muzquiz, C. Burbano, Cuadrado, C. Pedrosa, M.M. Ayet and A.U. Osagie, 2000. Effect of soaking, cooking and germination on the oligosaccharide content of selected Nigerian legume seeds. *Plt Foods Hum. Nut*., **55**:97-110.

Ogunkoya, M.O., F.O., Abulude, and A.B. Oni, 2006. Determination of anatomical, proximate, minerals, oxalate, tannin and phytate compositions of Cuban boa (*Epicrates anaquifer*). *J. of Envir. Agr. Food Chem.* **5**:1160-1166.

Onabanjo, O.O., C.O., Akinyami, and A., Agvonc, 2009. Characteristics of complementary foods produced from sorghum, sesame, carrot and crayfish. *J. of Nat. Sci. Engr. and Techno*. **8(1):**71-83.

Onimawo I.A., P.I., Akubor, 2012. Food Chemistry (Integrated Approach with Biochemcial background). 2nd edn. Joytal printing press, Agbowo, Ibadan, Nigeria.

Onimawo, I.A and P.I. Akubor, 2005. Food chemistry. Integrated Approach with Biochemical background. Ambik Press Ltd. Edo State.

Onwuka, G.I., 2005. Food analysis and Instrumentation. Theory and Practices. Naphthali Prints, Lagos.

Osborn, D.R and P. Voogt, 1978. Calculations of Calorific Value in the Analysis of Nutrients in Roots. Academic Press New York. Pp. 239-244.

Osman, N.M., A.M. Isam and E.E. Babiker, 2010. Fermentation and cooking of Sicklepod (*Cassia obtusifolia*) leaves: Changes in chemical and amino acid composition, anti-nutrients and protein fractions and digestibility. *Inter. J. Food Sci. Techno.* **45**:124-132.

PCC, 2008. Summary and Statistical Report of the 2007 Population and Housing Census. PCC of the Federal Democratic Republic of Ethiopia), Addis Ababa, Ethiopia.

Peleg, M., and E. B. Bagley, 1983. Physical properties of foods. Westport, CN: AVI Pub. Co.

Petterson, D.S., S. Sipsas, and J.B. Mackintosh, 1997. The Chemical Composition and Nutritive Value of Australian Pulses, 2nd edn. Grains Research and Development Corporation, Kingston, Australia.

Plahar, W.A. and N.T. Annan, 1994. Development of balanced protein-energy weaning foods based on local legumes and cereals. Report submitted to the Association of African Universities by Food Research Institute. Accra, Ghana.

Ramakrishna, V., P. Jhansirani, and P.R. Ramakrishna, 2006. Nutritional quality of storage proteins during germination of Indian bean (*Dolichos lablab var. lignosus*) Seeds. *World J. of Dairy and Food Sci.* **1(1):** 06-11.

Rao, P.U. and Y.G. Deoshthale, 1982. Tannin contents of pulses: varietal differences and effect of cooking and germination. *J. of the sci. of food and agr*. **33**:1013-1016.

Ratnavathi, C.V. and J.V. Patil, 2013. Sorghum utilization as food. *J. Nut. Food Sci.* **4**:247.

Ravi, R. and B. Suvendu, 2004. Flow behavior of chickpea (*Cicer arietinum* L.) flour dispersions: effect of additives. *J. Food Eng*., **65:**619-624.

Ravindran, V., G. Ravindran, and S. Sivalogan, 1994. Total and phytate phosphorus contents of various foods and feed stuffs of plant origin. *Food Chem.***50:**133–136.

Reddy, N.R., M.D. Pierson, S.K. Sathe and D.K. Salunkhe, 1989. Occurrence, distribution, content and dietary intake of phytate. In N.R.Reddy, M.D. Pierson, S.K. Sathe and D.K. Salunkhe (eds.) Phytates in cereals and legumes. CRC Press, Boca Raton, FL, USA. P. 39-56.

Reed, J. D., 1995. Nutritional toxicology of tannins and related polyphenols in forage legumes. *J. of Ani. Sci.*, **73:**1516-1528.

Rehman, Z.U. and W. H., Shah, 2001. Tannin contents and protein digestibility of black grams (*Vigna mungo*) after soaking and cooking. *Plt. Foods for Hum. Nut*. **56**: 265–273.

Rincon, F., M., Beatriz, and M.V., Ibanez, 1998. Proximate composition and antinutritive substances in chickpea (*Cicer arietinum* L.) as affected by the biotype factor. *J. of Sci. of Food and Agr*. **78**:382-388.

Rodriguez, B., and M., Kimura, 2004. Harvest plus handbook for carotenoid Analysis. Technical monograph series **2**: 8-20.

Rooney, L.W. and R.D. Waniska, 2000. Structure and chemistry of the sorghum caryopsis. In: Smith, C.W., Frederiksen, R.A. (Eds.), Sorghum: Origin, History, Technology, and Production. Wiley, New York, pp. 649–688.

Rosenthal, G.A. and M.R. Berenbaum, 1991. Herbivores-Their interactions with secondary plant metablolies, New York: Acadamic press.

Saleh, A.M., A.E. Salama, H.B. Salah and E.I. Abd-Elazim, 2012. Effect of Partial Substitution of Wheat Flour with Either Defatted Soybean or Chickpea Flours at Different Ratios on Rheological and Physical Properties of Dough, and Quality Characteristics of Biscuits**.** *J. of App. Sci. Res.*, **8(12):**5806-5817.

Salgado, P., J.P. Lallesa, R., Toulleca, M. Mouratob, F. Cabralb and J.P. Freire, 2001. Nutrient digestibility of chickpea (*Cicer arietinum* L.) seeds and effects on the small intestine of weaned piglets. *Ani. Feed Sci. and Techno*., **91:**197–212.

Salunkhe D.K., J.K. Chavan and S.S. Kadam, 1990. Occurrence, nature and composition. In Dietary Tannins: Consequences and Remedies, [DK Salunkhe, JK Chavan and SS Kadam, editors]. Boca Raton, FL: CRC Press, pp. 29–68.

Sandberg, A.S. and T. Andlid, 2002. Phytogenic and microbial phytases in human nutrition. *Inter. J. of Food Sci. and Techno*., **37**:823-833.

Sanoussi, A. F, A. Dansi, I. Bokossa-yaou , M. Dansi, M. Egounlety, L.O. Sanni and A. Sanni. 2013. Formulation and biochemical characterization of sweet potato (*Ipomoea batatas*) based infant flours fortified with soybean and sorghum flours. *Inter. J. Curr. Microbio. Appl. Sci*. **2(7)**: 22-34.

Saxena, A.K., M. Chadha and S. Sharma, 2003. Nutrients and antinutrients in chickpea (*Cicer arietinum* L.) cultivars after soaking and pressure cooking. *J. of Food Sci. and Techno.* **40**:493-497.

Shahidi, F., M. Naczk, 1995. Phenolic compounds in cereals and legumes. In: Food Phenolics: Chemistry, Effects, Applications. Technomic Publ. Co. Inc., Lancaster. pp13–18.

Shahzadi N., M.S, Butt, S. Rehman, and K. Sharif, 2005. Chemical Characteristics of Various Composite Flours. *Inter. J. of Agr. and Bio,* **7(1):**105-108.

Sharma, S., N. Yadav, A. Singh and R. Kumar, 2013. Nurtritional and antinutritional profile of newly developed chickpea (Cicer arietinum L.) varieties. *Inter. Food Res. J.*, **20(2):**805-810.

Shewry, P., 2007. Improving protein content and composition of cereal grain. *J. Cereal Sci.*, **46(3)**:239-250.

Shimelis T., K. Urga, C. Abuye and N. Retta, 2010. Improvement of energy and nutrients density of sorghum based weaning food using germination. *African J. of Food Agr., Nut. and Dev.* **10**: 2927-2942.

Siddhuraju, P., K. Becker and H.P. Makkar, 2000. Studies on the nutritional composition and antinutritional factors of three different germplasm seed materials of an underutilized tropical legume *Mucuna puriens* var. utilis. *J. of Agr. and Food Chem*. **48(12)**: 6048-6060.

Singh, S., C.S. Riar and D.C. Saxena, 2008.Effect of incorporating Sweetpotato flour to Wheat flour on the quality characteristics of cookies. *African J. of Food Sci.*, **2**: 65-72.

Smith, N.W. and R.A. Frederiksen, 2000. Sorghum: origin, history, technology and production, John Wiley and Sons Inc., New York, N.Y. 824.

Sokrab, A.M., A.M. Isam and E.E. Babiker, 2012. Effect of malting and fermentation on anti-nutrients, and total and extractable minerals of high and low phytate corn genotypes. *Inter. J. Food Sci. Techno.*, **47**:1037-1043.

Solomon A. and T. Zemene, 2008. Risk factors for severe acute malnutrition in children under the age of five: A case-control study. *Ethiopian J. Health Dev.*, **22(1)**:21-25.

Taylor, J.R., 2004. Grain production and consumption: Africa. In: C. Wrigley, H. Corke and C.E. Walker, Editors, *Encyclopedia of Grain Science*, Elsevier, London, pp. 70–78.

Taylor, J.R., L.I Ezeogu, K.G. Duodu and M.N Emmambux, 2008. Influence of cooking conditions on the protein matrix of sorghum and maize endosperm flours. *Cereal Chem*. **85**:397-402.

Taylor, J.R. and P.S. Belton, 2002. Sorghum. In Pseudocereals and Less Common Cereals ed. P. S. Belton and J. R. N. Taylor, pp. 25-91. Berlin: Springer.

Temple, V.J., E.J. Badamosi, O. Ladeji, and M. Solomon, 1996. Proximate composition of three locally formulated complementary foods. *West African J. of bio. Sci*., **5**:134-143.

Terrill, T.H., A.M. Rowan, G.B. Douglas and T.N. Barry, 1992. Determination of extractable and bound condensed tannin concentrations in forage plants, protein concentrates meals and cereal grains. *J. Sci. Food Agr*, **58**:321-329.

Tomlins, K.I., G. Ndunguru, K. Stambul. N. Joshua, T. Ngendello, E. Rwiza, R. Amour, B. Ramadhani, A. Kapande and A. Westby, 2007. Sensory evaluation and consumer acceptability of pale fleshed and orange fleshed sweet potato by school children and mothers with preschool children. *J. of the sci. of Food and Agr.* **87**:2436-2446.

Trussel, S.A. 2003. ABC of Nutrition, 4thed. BMJ Publishing Group, 24-30.

Ugwu, F. M. and N. A. Oranye, 2006. Effects of some processing methods on the toxic components of African breadfruit (*Treculia africana*). *African J. of Biotech.* **5**:2329-2333.

Undesi E.A., T.C. Odom, J.O. Nwaorgu, R.O. Emecheta and C.A. Ihemanma, 2012. Production and evaluation of the nutritional quality of weaning food formulation from roasted millet and mucuna cochinchinesis. *Sky J. of Food Sci*, **1(1):**1-5.

Urbano, G., M. Lo´pez-Jurado, J. Herna´ndez, M. Ferna´ndez, M.C. Moreu, J., Frias, C. M. Diaz-Polla´n, Prodanov and C. Vidal- Valverde, 1995. Nutritional assessment of raw, heated and germinated lentils. *J. Agr. Food Chem*, **43**:1871-1877.

Vaintraub, I.A. and N.A. Lapteva, 1988. Colorimetric determination of phytate in unpurifi ed extracts of seeds and the products of their processing. *Analysis Bioch.* **175**:227–230.

Vidal, V,C., J. Frias, I. Estrella, M.J. Gorospe, R. Ruiz and J. Bacon, 1994. Effect of processing on some anti-nutritive factors of lentils. *J. Agric. Food Chem*, **42**:2291-2295.

Vimala, B., B. Nambisan and B. Hariprakash, 2011. Retention of carotenoids in orange fleshed sweet potato during processing. *J. of Food Sci. and Techno*, **48**:520-524.

Viveros, A., A. Brenes, R. Elices, I. Arija and R. Canales, 2001. Nutritional value of raw and autoclaved kabuli and desi chickpea (*Cicer arietinum L.). British Plt Sci.*, **42**:242–251.

Waghorn, G.C., W.T. Jones, I.D. Shelton and W.C. McNabb, 1990. Condensed tannins and the nutritive value of herbage. Proc. NZ. Grass. Assoc. **51**:171-175.

Walker, A.F., 1990. The contribution of weaning foods to protein-energy malnutrition. *Nut. Res. Review*. **3**: 25-47.

Walter, L.H., F. Leenhardt, C. Coudrary and C. Remesy, 2002. Minerals and phytic acid interactions: is it a real problem for human nutrition? *Inter. J. of Food Sci. and Techno.* **37**:727-739.

Wang, N., D.W. Hatcher, R.T. Tyler. R. Toews and E.J. Gawalko, 2010. Effect of cooking on the composition of beans (*Phaseolus vulgaris* L.) and chickpeas (*Cicer arietinum* L.). *Food Res. Inter*, **43:** 589-594.

Wardlaw, G.M. and P.M. Insel, 2000. Contemporary Nutrition, 4th ed. McGraw- Hill companies, pp 444 -458.

Weinges, K. and P. Plieninger, 1999. Erinnerungen an Karl Johann Freudenberg. *Eur. J. Org. Chem*, **3**:707-736.

White, T., 1957. Tannins - their occurrence and significance. *J. of Sci. and Food Agr.* **8**:377-385.

Whitney, E.N. and S.R. Rolfes, 1999. Understanding Nutrition, 8th ed. Wadsworth publishing company, USA., PP 234-260.

WHO/UNICEF., 1998. Complementary feeding of young children in developing countries. Geneva, 167-170.

Wood J.A. and M.A. Grusak, 2007. Nurtional value of chickpea. *Intern. J. of Food Sci. and Nut*, **55**:101-142.

Woolfe, J.A., 1992. Sweet potato: An untapped Food Resource Cambridge University press, Cambridge, M.A., PP: 643.

Wu, H., Q., Wang, T. Ma and J. Ren, 2009. Comparative studies on the functional properties of various protein concentrate preparations of peanut protein. *Food Res. Inter.*, **42**: 343–348.

Yewelsew A., J. S., Barbara, J. H., Margaret, E. G., Gail, 2006. Nutritive value and Sensory Acceptability of corn- and kocho-based foods Supplemented with Legumes for infant Feeding in Southern Ethiopia, *African J. of Food Agr. Nut. and Dev.*, **6(1):**1-19

Yusuf, A.A., H. Ayedun and L.O. Sanni, 2008. Chemical composition and functional properties of raw and roasted Nigerian benniseed (*Sesamum indicum*) and Bambara groundnut ((*Vigna subterranean*). *Food Chem.*, 111: 277-282.

Yusufu, P.A., F.A. Egbunu, S.I. Egwujeh, G.L. Opega and M.O. Adikwu, 2013. Evaluation of Complementary Food Prepared from Sorghum, African Yam Bean (*Sphenostylis stenocarpa*) and Mango Mesocarp Flour Blends. *Pakistan J. of Nutr*, **12 (2):** 205-208.

Zhang, Y.J., T. Abe, and T. Tanaka, 2001. Phyllanemblinins A-F, new ellagitannins from Phyllanthus emblica. *J. Nat. Prod*, **64**:1527-1532.

APPENDICES

8. APPENDICES

Appendix Table 1 Analysis of variance p-value of proximate composition

Regression	Moisture	Protein	Fat	Fiber	Ash	CHO	Calorie
Linear	0.049	0.080	0.030	0.459	0.253	0.019	0.015
Quadratic	0.007	0.055	0.105	0.283	0.106	0.011	0.131
Sorg*Chick	0.073	0.276	0.019	0.197	0.135	0.092	0.745
Sorg*OFSP	0.001	0.021	0.508	0.275	0.023	0.002	0.040
Chick.*OFSP	0.533	0.031	0.950	0.372	0.387	0.028	0.220
Lack of fit	0.143	0.459	0.414	0.336	0.880	0.362	0.614

Where: Sorg.= Sorghum Chick.= Chickpea OFSP = Orange fleshed sweet potato CHO = Carbohydrate

Appendix Table 2 Analysis of variance p-value mineral content and β-Carotene

Regression	Iron	Zinc	Calcium	β-Carotene
Linear	0.738	0.074	0.007	0.000
Quadratic	0.168	0.009	0.031	0.001
Sorg*Chick	0.061	0.155	0.643	0.346
Sorg*OFSP	0.173	0.005	0.007	0.009
Chick.*OFSP	0.195	0.730	0.046	0.000
Lack of fit	0.309	0.706	0.693	0.484

Where: Sorg.= Sorghum Chick.= Chickpea OFSP = Orange fleshed sweet potato

Appendix Table 3 Analysis of variance p-value of anti nutritional factors and Functional properties

Regression	Phytate	Tannin	Bulk density	WAC	Viscosity index
Linear	0.360	0.000	0.842	0.008	0.253
Quadratic	0.138	0.000	0.834	0.021	0.478
Sorg*Chick	0.033	0.950	0.522	0.007	0.568
Sorg*OFSP	0.524	0.000	0.963	0.557	0.696
Chick.*OFSP	0.299	0.043	0.547	0.225	0.149
Lack of fit	0.357	0.962	0.245	0.583	0.925

Where: Sorg.= Sorghum Chick.= Chickpea OFSP = Orange fleshed sweet potato

Appendix Table 4 Analysis of variance p-value of sensory evaluation

Regression	Color	Aroma	Taste	Mouth feel	OA
Linear	0.216	0.034	0.513	0.391	0.224
Quadratic	0.009	0.013	0.038	0.016	0.030
Sorg*Chick	0.017	0.155	0.032	0.006	0.015
Sorg*OFSP	0.002	0.002	0.011	0.014	0.022
Chick.*OFSP	0.170	0.044	0.323	0.157	0.093
Lack of fit	0.000	0.000	0.000	0.000	0.000

Where: Sorg.= Sorghum Chick.= Chickpea OFSP = Orange fleshed sweet potato

Appendix Table 5 Estimated regression coefficients of proximate compositions of individual and mixed product

Term	Moisture		Ash		Fiber		Fat		Protein		CHO	
	RC	SE	RC	SE	RC	SE	RC	SE	RC	SE	RC	SE
Sorg.	21.5	4.872	5.13	1.588	-10.22	5.720	8.55	1.995	17.80	4.378	57.19	8.090
Chick.	9.9	8.691	4.57	2.833	-6.11	10.203	17.14	3.560	28.79	7.809	45.74	14.431
OFSP	54.7	12.781	12.54	4.166	6.81	15.004	-1.19	5.234	37.60	11.483	-10.49	21.222
Sorg*Chick	-46.1	23.066	-12.22	7.518	37.43	27.078	-26.50	9.447	-23.88	20.723	71.32	38.298
Sorg*OFSP	-114.4	25.010	-21.80	8.152	33.94	29.360	-7.03	10.243	-61.39	22.470	170.70	41.526
Chick.*OFSP	-15.5	24.021	-7.08	7.829	-26.34	28.199	0.63	9.838	-54.29	21.582	102.58	39.884
R^2	91.27		88.33		86.43		97.81		97.20		86.96	

Sorg.= Sorghum Chick.=Chickpea OFSP=Orange fleshed sweet potato RC= Regression coefficient SE= Standard error

R^2= Determination coefficient

Appendix Table 6 Estimated regression coefficients of mineral content and β carotene

Term	Energy		Iron		Zinc		Calcium		β carotene	
	RC	SE	RC	SE	RC	SE	RC	SE	RC	SE
Sorg.	376.93	30.79	28.49	8.737	2.872	0.5356	77.4	32.81	-740	622.7
Chick.	452.38	54.91	37.25	15.584	1.062	0.9554	98.2	58.52	142	1110.7
OFSP	97.71	80.75	16.48	22.917	5.214	1.4049	423.9	86.06	11617	1633.4
Sorg*Chick	-48.72	145.73	-87.45	41.358	3.896	2.5355	-74.3	155.32	2916	2947.7
Sorg*OFSP	373.92	158.02	-65.88	44.843	-9.724	2.7491	-565.8	168.41	-10424	3196.1
Chick.*OFSP	198.79	151.77	-59.88	43.071	-0.938	2.6405	-368.9	161.75	-15789	3069.8
R^2	97.40		93.79		98.86		93.14		98.72	

Sorg.= Sorghum Chick.=Chickpea OFSP=Orange fleshed sweet potato RC= Regression coefficient SE= Standard error

R^2= Determination coefficient

Appendix Table 7 Estimated regression coefficients of anti-nutritional factors and functional properties

Term	Phytate		Tannin		Bulk Density		Water absorption capacity		Viscosity index	
	RC	SE	RC	SE	RC	SE	RC	SE	RC	SE
Sorg.	320	94.93	0.9447	0.1623	-2.155	1.538	7.6	5.215	20.3437	3997
Chick.	512	169.33	1.0494	0.2896	-8.560	2.743	7.0	9.303	121.862	7130
OFSP	100	249.01	0.7459	0.4258	11.205	4.033	133.8	13.681	61.6461	10485
Sorg*Chick	-1110	449.38	-0.5101	0.7684	24.346	7.278	1.6	24.689	-1.11645	18921
Sorg*OFSP	-322	487.25	-0.0401	0.8332	-4.797	7.892	-171.1	26.769	-0.82466	20516
Chick.*OFSP	-512	467.99	-0.4985	0.8003	-9.794	7.580	-59.6	25.711	-3.08422	19705
R^2	80.95		99.56		76.76		94.47		89.94	

Sorg.= Sorghum Chick.=Chickpea OFSP=Orange fleshed sweet potato RC= Regression coefficient SE= Standard error

R^2= Determination coefficient

Appendix Table 8 Estimated regression coefficients of sensory evaluation

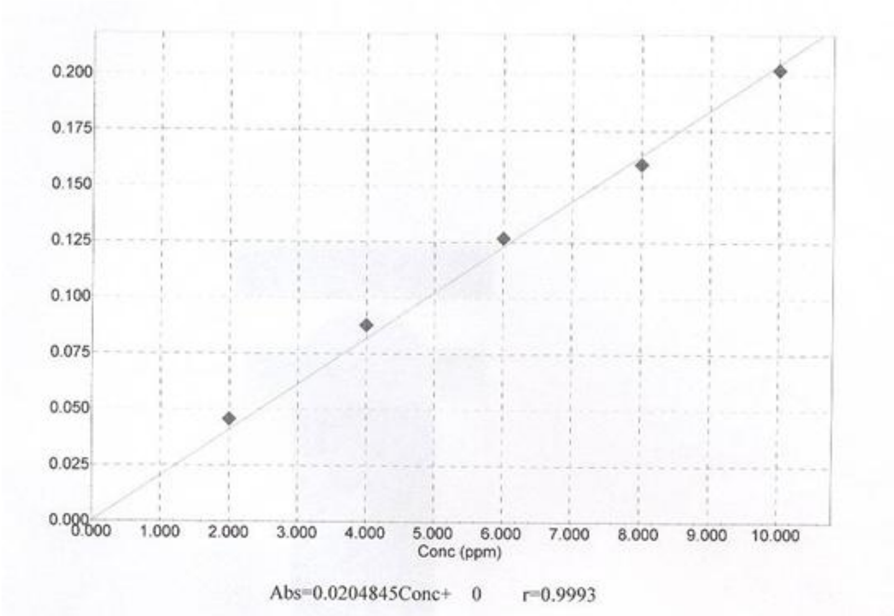
Term	Color		Aroma		Taste		Mouth feel		Overall acceptability	
	RC	SE	RC	SE	RC		RC	SE	RC	SE
Sorg.	37.2	8.607	20.9	7.237	34.1	10.13	39.9	10.43	35.9	11.65
Chick.	36.0	15.353	16.4	12.908	33.7	18.07	56.2	18.60	57.1	20.78
OFSP	80.0	22.577	79.9	18.983	65.7	26.58	63.4	27.35	74.5	30.55
Sorg*Chick	-128.3	40.744	-52.7	34.257	-119.1	47.96	-172.4	49.36	-161.8	55.14
Sorg*OFSP	-188.8	44.177	-152.6	37.144	-161.4	52.00	-159.6	53.52	-162.7	59.79
Chick.*OFSP	-65.9	42.431	-82.2	35.676	-51.9	49.95	-78.7	51.41	-106.7	57.42
R^2	79.35		72.17		66.37		74.06		71.69	

Sorg.= Sorghum Chick.=Chickpea OFSP=Orange fleshed sweet potato RC= Regression coefficient SE= Standard error

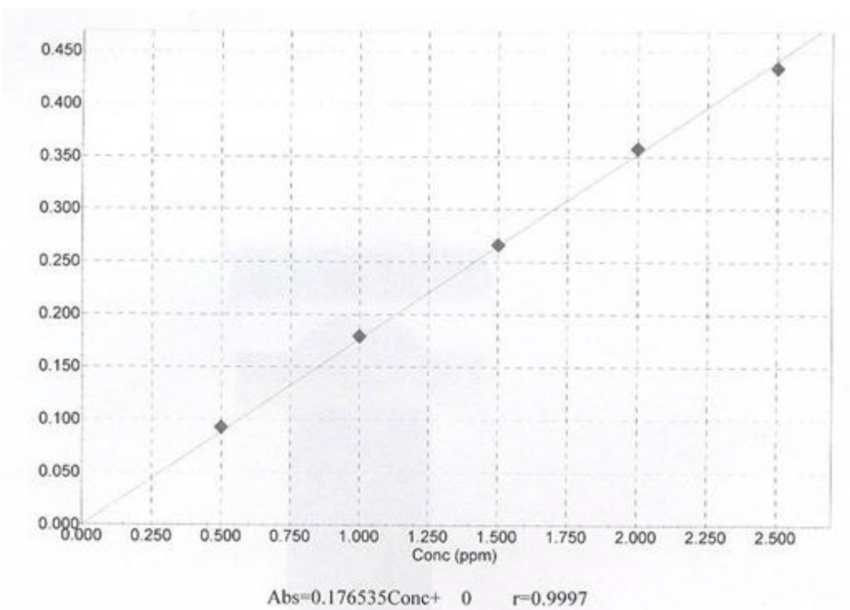
R^2= Determination coefficient

Appendix 9: Calibration curve of Iron, Zinc and Calcium

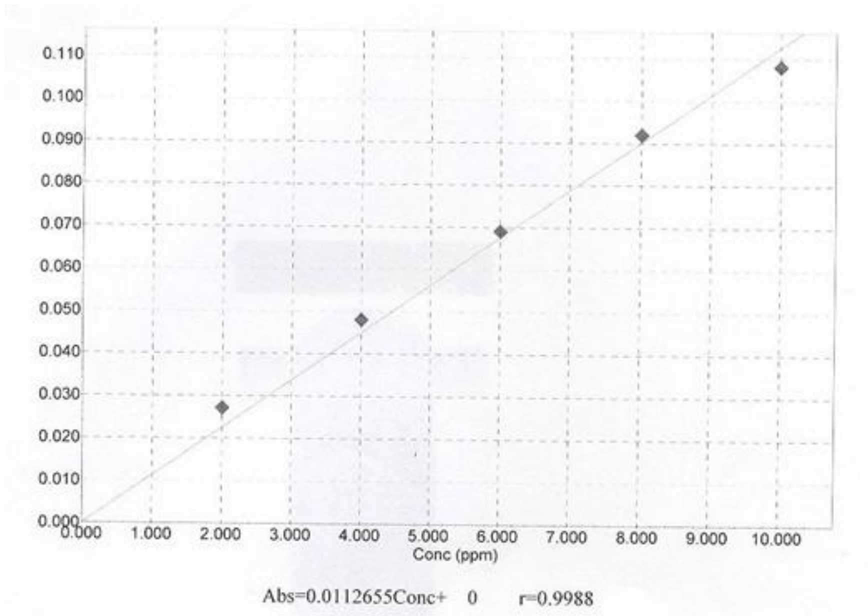
I. Iron calibration curve



II. Zinc Calibration curve

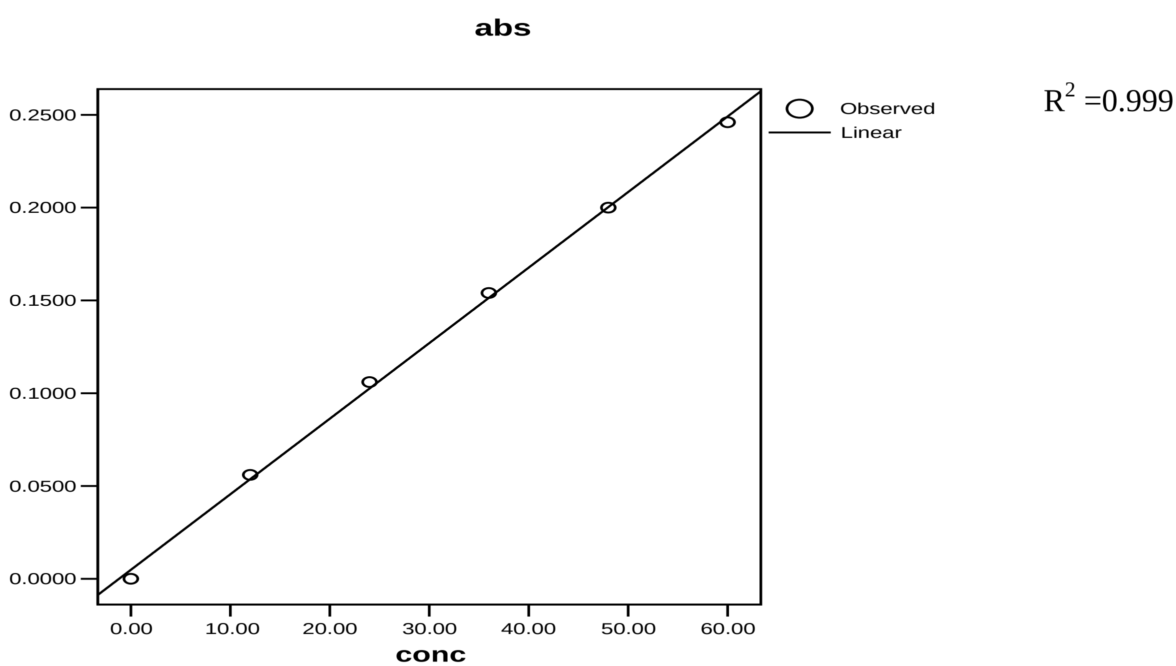


III. Calcium calibration curve



Appendix 10: Calibration curve of tannin

IV. Tannin calibration curve



Appendix 11: Sensory evaluation questioner form

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

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

Sample code	Color	Aroma	Taste	Mouth feel	Overall acceptability

Appendix 12: Questioners

The purpose of this questionnaire is to collect information related to the knowledge, practice and attitudes of farmers on the utilization of Sorghum, Chickpea and Orange fleshed Sweet Potato as baby food

Personal information

Name________________________________Kebele____________Maritalstatus__________________

Family size____________Educational back ground_____________

1. Which crop is staple food in your area?
    a. Sorghum
    b. Orange fleshed Sweet potato

c. Chickpea

d. Any other (state)

2. Where do you get your staple food which is selected in question no 1?

   a. Purchased b. On farm c. Both d. Any other means

3. Do you know orange fleshed sweet potato?

   Yes ☐ No ☐

4. If your answer is no, do you grow it if you are provided with the cutting?

   Yes ☐ No ☐

5. Which kind of food or foods do you prepare from these crops?

Sorghum	Chickpea	OFSP

6. How is your staple food usually eaten from these crops?

   a. "Nifro" b. "kolo" c. Injera d. Bread/kita e. Porridge f. All

7. Can young children eat the staple in the way it is usually eaten by the family?

   ☐ YES ☐ NO

8. If the answer is no, can mothers suggest ways to make the staple in the family meal easy for young children to eat, such as mashing and softening

   ____

   ____

9. What type of food do you feed for your baby permanently? ____________________

   ____

10. Young children feed pulse and legume crops? YES ☐ NO ☐

11. If no, what are the reasons? ______________________________________

    ____

12. Do you prepare baby food from sorghum, chickpea and OFSP?

    Yes ☐ No ☐

13. If the answer is yes, what type of food do you prepare?

    a. Porridge b. Gruel c. "kita"

14. Have you ever received any training on preparation of baby food from these crops? If yes, who gave the training?

Training	Kind of food	Source of training
Yes		
No		

15. What is the extent of your awareness about the food value of Sorghum, Chickpea and Orange fleshed sweet potato?

	Very well	well	Some how	Very little	Nothing
Sorghum					
Chickpea					
OFSP					

16. If you feed sorghum, chickpea and OFSP, what other crops do you mix with?

	No mix	Mixed with	Proportion	Purpose of each ingredient
Sorghum				
Chickpea				
OFSP				

Appendix 13: Amharic translated questioner

የዚህ መጠይቅ ጥቅም በዳውሮ ዞን ሎማ ወረዳ አካባቢ አ/አደሮች በማሽላ፤ ሽምብራና ብርቱካናማ ስኳር ድንች ላይ ያላቸውን እውቀት፤ ተግባርና አመለካከተ መረጃ ለመሰብሰብ ነው፡፡

የተሳታፊው

ሥም---ቀበሌ-------------------------------የጋብቻ ሁኔታ---------------------------የቤተሰብ ብዛት------
የትምህርት ደረጃ-----------------------------

1. በአካባቢያችሁ የትኛውን የእህል አይነት ነው በመደበኛነት የምትጠቀሙት
   ሀ. ማሽላ
   ለ. ብርቱካናማው ስኳር ድንች
   ሐ. ሽምብራ

መ. ሌላ ካለ ይጠቀስ

2. በተራ ቁጥር 1 ላይ የመረጣችሁትን መደበኛ ምግባችሁን ከየት ነው የምታገኙት

ሀ. ከገበያ ለ. ከእርሻ ሐ. ከሁለቱም መ. ሌላ ካለ ይገለፅ

3. ብርቱካናማውን ስኳር ድንች ያውቁታል;

አዎ ☐ አላውቀዉም ☐

4. በተራ ቁጥር3 ላይ መልስዎ አላውቀውም ከሆነ፤ ቁርጥራጩንስ ቢያገኙ መትከል/ማምረት/ ይፈልጋሉ;

አዎ ☐ አልፈልግም ☐

5. ከሚከተሉት የእህል አይነቶች ውስጥ ምን አይነት ምግብ በአብዛኛው ይሠራሉ;

ከማሽላ	ከሽምብራ	ከ ብርቱካናማው ስኳር ድንች

6. መደበኛ ምግባችሁን በምን አይነት መልኩ ነው በብዛት የምትመገቡት;

ሀ. ንፍሮ ለ. ቆሎ ሐ. እንጀራ መ. ዳቦ/ቂጣ ሠ. ገንፎ ረ. ሁሉም

7. ህጻናት ልጆች መደበኛ ምግቦችን ይመገባሉ?

አዎ ☐ አይመገቡም ☐

8. መልስዎ አይመገቡም ከሆነ ምክንያቱ ምንድነው? እናቶችስ ምን ይመክራሉ? ህፃናት በቀላሉ እንዲመገቡት ለማድረግ--------

----

----

9. ህፃናት በቋሚነት ምን ዓይነት ምግብ ይመገባሉ?---

----

10. ህፃናትን የቅባት ና ጥራጥሬ እህሎችን ትመግቡዋቸዋላችሁ ?

አዎ ☐ አይመገቡም ☐

11. ተራ ቁጥር 10 ላይ አይመገቡም ከሆነ መልስዎ ለምን?---

----

12. ለልጆችዎ ከማሽላ፤ ሽምብራና ብርቱካናማው ስኳር ድንች ምግብ ይሰሩላቸዋል?

አዎ ☐ አይራም ☐

13. ተራ ቁጥር 12 ላይ መልስዎ አዎ ከሆነ ምን አይነት ምግብ ነው የሚሰሩላቸው?

ሀ. ገንፎ ለ. አጥሚት ሐ. ቂጣ

14. ከዚህ በፊት በህፃናት የምግብ አሰራር ላይ ስልጠና ተሰቶዋችሁ ያውቃል?

ስልጠና	የስልጠናው አይነት	ስልጠናውን የሰጠው አካል
ሰልጥነኛለሁ		
አልሰለጠንኩም		

15. ማሽላ፤ ሽምብራና ብርቱካናማው ስኳር ድንች ላይ ስለ ምግብ ንጥረ ነገሩና ለምግብነት ስለመዋሉ ምን ያክል እውቀት አለዎት?

	እጅግ በጣም	በጣም	የተወሰነ	ጥቂት	ምንም
ማሽላ					
ሽምብራ					
ብርቱካናማው ስኳር ድንች					

16. ማሽላ፤ ሽምብራና ብርቱካናማው ስኳር ድንችን ለምግብነት የምትጠቀሙ ከሆነ ከምን ዓይነት እህሎች ጋር ይቀላቅሉዋቸዋል?

	አይቀላቀልም	ከ----	መጠኑ	ለምንድነው የሚቀላቀለው
ማሽላ				
ሽምብራ				
ብርቱካናማው ስኳር ድንች				