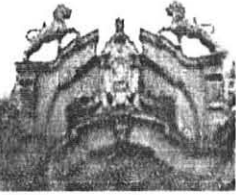
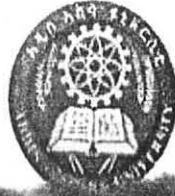


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School of Graduate Studies
Food science and nutrition program**

**EFFECT OF BLENDING ON SELECTED SWEET POTATO FLOUR WITH
WHEAT FLOUR ON NUTRITIONAL, ANTINUTRITIONAL AND SENSORY
QUALITIES OF BREAD**

**A Thesis Submitted to the School of Graduate Studies of Addis Ababa University in
Partial Fulfillment of the Requirements for the Degree of Master of Science (MSc)
in Food Science and Nutrition**

By

Endrias Dako Keshamo

Advisors: Major advisor: Nugussie Retta (Professor)

Co-advisor: Gulelat Desse (PhD, Associate Professor)

May, 2012

Addis Ababa

ADDIS ABABA UNIVERSITY SCHOOL OF GRADUATE STUDIES

FOOD SCIENCE AND NUTRITION PROGRAM

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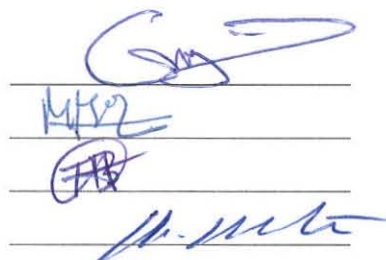
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Acknowledgements

First of all, I thank God for giving me strength and life health throughout this study.

I would like to express my sincerest appreciation and gratitude to my advisors Professor Nugussie Retta and Dr. Gulelat Desse for their professional guidance, encouragement, valuable comments from beginning to final write up of this thesis.

I want to acknowledge Mr. Tilahun Bekele, who provided all possibilities to get me laboratory space and materials. I gratefully thank Ms. Woinshet Abera, Mr. Debebe and Mr. Muluneh for their technical supports during my laboratory work. I specially thank Dr. Melesse Abdisa, Mr. Abriham Shumbulo, Mr. Ashagrie Zewdie, Mr. Dawid Gashu and Mr. Adugna Melkie for their vital comments and encouragement.

My special thanks go to my wife Ms. Woletu Degefu and my brother Mr. Samuel Dako for their unreserved support in all possible ways to complete the whole study.

I gratefully acknowledge Addis Ababa University and Boloso Bombe Woreda for their financial support for this work. I gratefully thank Food Science and Nutrition Program of Addis Ababa University, Areka Agricultural Research Center, Entoto Technical and Vocational Education Training, Ethiopian Health and Nutrition Research Institute and Chemistry Department of Addis Ababa University for their facilitating, cooperation and technical support during my study.

My last but not least thanks go to Mr. Aman Malako, Mr. Oycha Oshine, Mr. Tamirat Balcha, Mr. Markos Desalegn and all others who directly or indirectly contributed to the success of this work.

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Acronyms

AACC	American Association of Cereal Chemist
AARC	Awassa Agricultural Research Center
AAU	Addis Ababa University
ANOVA	Analysis of Variance
ArARC	Areka Agricultural Research Center
B.D.L.	Below detection levels
CIP	International Potato Center
EHNRI	Ethiopian Health and Nutrition Research Institute
LSD	Least Significant Differences
NaCl	Sodium Chloride
NB	Remember
NGOs	Non Governmental Organizations
OFSP	Orange Fleshed Sweet Potato
OSP	Orange Sweet Potato
POSP	Peeled Orange Sweet Potato
PWSP	Peeled White Sweet Potato
PYSP	Peeled Yellow Sweet Potato
SNNPR	Southern Nation and Nationalities People Regions
SP	Sweet Potato
SPF	Sweet Potato Flour
TVET	Entoto Technical and Vocational Education Training
UD	Undetected
UOSP	Unpeeled Orange Sweet Potato
UWSP	Unpeeled White Sweet Potato
UYSP	Unpeeled Yellow Sweet Potato
WAC	Water Absorption Capacity
WF	Wheat Flour
WSP	White Sweet Potato
YSP	Yellow Sweet Potato

Abstract

*Nutritional and antinutritional status of yellow, white and orange fleshed sweet potatoes (*Ipomoea batatas* L. Lam) in their raw roots unpeeled and peeled as well as effect of blending ratio on nutritional, antinutritional and qualities attributes of breads made from orange sweet potato and wheat composite flours were studied. Nutritional and antinutritional values of three sweet potato varieties were significantly ($p < 0.05$) varied due to cultivar, processing and interaction. Orange sweet potato variety contains highest level of moisture, fat, ash, carbohydrate, energy, calcium and iron in unpeeled and fiber, moisture, fat, ash, calcium, iron and zinc in peeled. On the other hand, yellow sweet potato variety contains highest level of protein, phytate, in both unpeeled and peeled while highest value of fiber, oxalate and tannin in unpeeled. White sweet potato variety was found in intermediate position for nutrients compared to other cultivars. Due to peeling, fat, carbohydrate and energy values were significantly increased but all other parameters were significantly decreased. Because of its potential source of nutrients orange sweet potato cultivar was selected for bread making and six blending ratios of its flour with wheat flour (0:100, 5:95, 10:90, 15:85, 20:80 and 25:75) were designed. Wet gluten and water absorption capacity was decreased and increased, respectively as blending ratio of sweet potato flour increases. Increase sweet potato flour in blending ratio significantly increased loaf weight, moisture, ash, fiber, carbohydrate, calcium, iron and zinc content of breads and decreased in loaf size, protein, fat, energy, phosphorus and phytate, of the breads. Appearance, aroma, taste, mouth feel and overall acceptability of control bread were more preferred than sweet potato flour supplemented breads. However, breads made using 15% sweet potato flour supplemented accepted by consumers, this leads to conclusion that nutritional improved, antinutritional reduced and consumer acceptable breads can be prepared by supplementing up to 15% SPF in WF.*

Key words: Antinutritional Factors, Blending ratio, Breads, Functional Properties, Mineral, Proximate, Quality Parameters, Sensory Attributes, Sweet potato, Variety.

1. Introduction

1.1. Background

Root and tuber crops refer to any growing plant that stores edible material in underground root, corm or tuber (Ugwu, 2009). Many of the developing world's poorest farmers and food insecure people are highly dependent on root and tuber crops as a source of food, nutrition and cash income (Scott *et al.*, 2000). The nutritional value of root and tuber crops lies in their potential ability to provide one of the cheapest sources of dietary energy in the form of carbohydrates. The amount of energy supplied by these crops is about one third of that of an equivalent weight of grains such as rice or wheat because these crops have high water content than cereals. However, the high yields of these root and tuber crops ensure an energy output per hectare per day which is considerably higher than that of grains (Woolfe, 1987).

In Ethiopia, sweet potato (*Ipomoea batatas* L. Lam) production ranks third after Enset (*Enset ventricosum* (W.) Cheesman) and potato (*Solanum tuberosum* L.) compared to other root and tuber crops. It is one of the major traditional food crops in the country. The crop cultivation is common in densely populated areas of the South, South-West and Eastern parts of the country and Southern Nation and Nationalities People Regions (SNNPR). It is an important food crop during hunger periods in areas such as Wollaita, Sidama, Kanbata Tanbaro, Gamo Gofa and Hadiya zones in SNNPR from February to May (Endale *et al.*, 1994).

Sweet potato is an attractive crop among farmers due to its high productivity, high caloric content, and good taste; it tolerant adverse environmental conditions such as drought, it requires low soil fertility, high rainfall and very little labor and care (CIP, 1995). In addition to these attributes, it has short production cycle, high nutritional value and sensory attributes in terms of flesh colors, taste and texture (Woolfe, 1992; Bovell-Benjamin, 2007; ILSI, 2008). Moreover, it contributes to food security and farmers' income in countries like Ethiopia (Terefe and Geleta, 1994).

Currently different cultivars of sweet potatoes are cultivated and consumed in Ethiopia. These cultivars contain different skin colors (e.g. pink, cream, orange and white) and flesh colors (e.g.

white, cream, orange and yellow). As with all crops the nutritional status of sweet potato cultivars vary from place to place depending on the climate, soil type, the crop variety and other factors (Ingabire and Hilda, 2011). Depending on the variety, sweet potatoes are rich in carbohydrates, dietary fiber, ash, β -carotene, minerals and other nutrients (Woolfe, 1992; Bovell-Benjamin, 2007; ILSI, 2008). However, with all its desirable traits, sweet potatoes contain potential plant toxins and antinutritional factors such as phytate, oxalate and tannin (Olayiwola *et al.*, 2009; Eluagu and Onimawo, 2010) that affect the nutrient utilization in the body.

Bread is a food product basically formed from flour, water, salt and yeasts. Bread flour is commonly made from wheat but it can be produced from other cereals like maize, rye, barley, rice and non-grain plants. Flour is the major basic ingredient in bakery products. Due to its important characteristics, wheat flour is the main ingredient in most types of breads (Aboaba and Obakpolor, 2010). Bread contains a good source of nutrients, such as macronutrients (carbohydrates, protein and fat) and micronutrients (minerals and vitamins) that are essential for human health to all population. However, the nutrient contents of bread products are depend on the chemical composition and baking processes used (Mohammed *et al.*, 2008).

Bread mainly produced form wheat flour but it can also be produced from composite flour such as a mixture of wheat and non wheat flours or wholly non wheat flour (David, 1992). The use of composite flour is advantageous in bread making for developing countries as it promotes high-yielding native plant species, increases nutritional values and enhances domestic agriculture production (Jolaosho, 2010). The goal of earlier researcher with composite flours was to save the largest possible percentage of wheat flour in the production of certain baked products. However, recently some research findings had showed that composite flour in new product development was used to improve nutritional value and sensory quality of the final products (Ammar *et al.*, 2009; Mepba *et al.*, 2007; Shoukat *et al.*, 2006).

Development in technology and research area showed that composite flours of sweet potato processed in to different food products for various purposes. A variety of food products such as doughnuts, biscuits, cakes, breads, cookies, fried chips, ice cream, porridge, breakfast foods and weaning foods have been made from sweet potato composite flour (Greene *et al.*, 2003 ; Truong and Ramesh, 2010). Sweet potato flour can serve as source of nutrients (carbohydrates, protein,

dietary fiber, beta-carotene, minerals (Ca, P, Fe and K) and can also add natural sweetness, color and flavor to processed food products (Woolfe, 1992). Hence, the development of appealing processed products from sweet potatoes play a major role in raising awareness on the potential use of the crop around the world. Thus, this study will be conducted firstly with the aim of selecting sweet potato variety with high nutritive value and low antinutritive factors among three sweet potato varieties (yellow-fleshed, white-fleshed and orange-fleshed) currently cultivated and consumed in Ethiopia. Secondly to determine the appropriate substitution level of selected variety of sweet potato flour for wheat flour in bread making.

1.2. Statement of the problem

Absolute poverty, poor health and sanitary conditions, limited knowledge of nutritional matters and fluctuations in incomes are some of the principal reasons for the high prevalence of malnutrition (Anderson, 1981). Improved nutrition is directly linked to expanded high nutritive food production. The nutritional quality of food can be improved by various practices, such as application of fertilizers, selection of varieties with high nutritional status and genetic modification of plants (Chaudhary, 1984).

Ethiopia has a wide range of agro-climatic conditions and cropping system in the country is highly diversified with a wide variety of cereals, vegetables, tuber and root crops (CSA, 1995). Among root and tuber crops sweet potato is one of the third important crop after enset and potato (Endale *et al.*, 1994). The total area under sweet potato in Ethiopia is 75000ha with an average productivity of 8t/ha (Assefa *et al.*, 2007). Currently different sweet potato cultivars are grown in the country in which most of rural people's diet depends on them. However, the nutritive value and antinutritive factors content varies depending on these cultivars. But farmers might be randomly cultivate and consume among these varieties due to lack of documented nutritional information about them. Such that producers and consumers should know the nutritional status of these varieties before cultivation and consumption in order to select high nutritive variety to improve their nutritional status.

An increased consumption of dietary fiber in daily diet has been recommended by nutritionists to improve health. High dietary fiber content of food is one of the most important factors in terms of developing healthy diets to reduce the incidences of cardiovascular diseases, diabetes, obesity

and reduction of glucose metabolism and promotion of the growth of beneficial gut micro flora (Brennan, 2005). Depending on cultivars, sweet potatoes are low in protein but rich in dietary fiber and carbohydrate content so a successful combination of sweet potato variety with high nutritive value with wheat flour for bread production would be nutritionally advantageous. Fiber is an important nutritional contributor of sweet potatoes in human diet. So that integration of wheat flour and sweet potato flour enhance the fiber content of bread and may have a significant effect on human health (Anton, 2008).

1.3. Significance of the study

The results of this study will have the following significances:

- + It provides necessary information about nutritional composition and antinutritional factors of yellow, white and orange fleshed sweet potato varieties such that the producers select and cultivate variety with high nutritive value in order to improve nutritional status in their diet.
- + It contributes in overcoming prevalence of malnutrition with providing nutritional knowledge to producers and daily consumption of fiber rich diet from such blended products.
- + It provides knowledge development in bread making form sweet potato-wheat flour combination.
- + It can be used as a base line data for further research in the same area like to compare nutritional status of other varieties of sweet potato and new product development by using sweet potato flour.
- + It can be used as reference material for students, teachers and other researchers in related areas.

1.4. Objectives

General objective

To study nutritional status of three sweet potato cultivars and the possibility of blending sweet potato flour to wheat flour to produce breads and to evaluate nutritional, antinutritional factors, quality and sensory attributes of breads.

Specific objectives

- ◆ To determine and compare proximate composition, mineral content and antinutritional factors of yellow, white and orange fleshed sweet potato (*Ipomoea batatas* (L.) Lam) varieties.
- ◆ To select sweet potato variety with high nutritional status and low antinutritional factors among the three sweet potato cultivars and use it in bread making by blending the flour with wheat.
- ◆ To determine functional properties of the blended flours.
- ◆ To assess the effect of blending ratio on the proximate composition, mineral content and anti-nutritional factors of the breads.
- ◆ To evaluate the effect of blending ratio on quality and sensory attributes of breads.

2. Literature review

2.1. Origin and distribution of sweet potato

Sweet potato (*Ipomoea batatas* L. Lam) is originated in Central America or tropical South America (Terefe, 2003). Indigenous South Americans have cultivated sweet potatoes for thousands of years. The crop was spread to other parts of the world such as Polynesia and New Zealand during the 8th century, into China during the 14th century, into Japan during the 17th century and in to the tropical areas of Africa, Europe, China, India and Indonesia during the 16th century (Janssens, 2001). Compared to other crops, the storage root of sweet potato is able to grow at an accelerating rate in various environmental conditions, thus multiplying in quantity in a short period of time. For that reason, sweet potato spread throughout Asia, Africa and Latin America during the 17th and 18th centuries. Since then sweet potato has become one of the most grown crops in Asia, Africa and America and so did the demand for sweet potato among consumers (Choong, 2008). Globally, sweet potato is ranked as the seventh most important food crop after wheat, rice, maize, potato, barley and cassava. Among all the root crops that are consumed, sweet potato ranks second only to the potato in economic importance (Horton, 1988 as cited in Choong, 2008).

2.2. Sweet potato production and uses in Ethiopia

Ethiopia is in the tropical zone has three climatic zones according to the elevation. Tropical zone (Kola) is hot and humid, below 1830 meter altitude sea level and has an average annual temperature of 27⁰C with annual rainfall of about 510mm. Subtropical zone (Woina dega) is warm and includes the high land areas of 1830 to 2440 meter altitude sea level and has an average annual temperature of 22⁰C, with annual rainfall between 510mm and 1530mm. Cool zone (Dega) is above 2440 meter altitude sea level with an average annual temperature of about 16⁰C and annual rainfall between 1270 and 1280mm. Sweet potato is adapted to the tropical zone (Kola) and subtropical zone (Woina dega) areas of the southern, southwestern and eastern parts of the country (Terefe, 2003).

The climate and soil conditions of Ethiopia are very favorable for the production of sweet potato. According to FAO (2000), world's average sweet potato production is estimated to be 14.8 tons

per hectare compared to 8 tons per hectare in Ethiopia. The country has 73,918,505 people (UNFPA, 2008) and is second most populous country in Africa (U.S. Census Bureau, 2009). Sweet potato is one of the most important staple root crops among 20 million or more Ethiopians. Area of cultivation is increasing from 40,000 to 75000 hectares as it requires less agricultural inputs (FAO, 2000). It is used as source of food and income for the poor and needy farmers in sweet potato producing areas. The different parts of sweet potato producing area used the crop for various purposes: the root for consumption and sale, the aboveground part for planting material, sale, feed for livestock and soil conservation (Endrias *et al.*, 2006). In Ethiopia the potential yield of sweet potato under research reaches up to 500 quintals per hectare. On-station and on-farm research with improved management practices indicated that the root yield of sweet potato ranged between 175 and 350 quintals per hectare. However, because of poor management practices the yield under farmer's condition is low. It is as low as 50 quintals per hectare (Getahun *et al.*, 2006).

In Ethiopia, among root crops, sweet potato production ranks third after enset (*Enset ventricosum* (W.) Cheesman) and potato (*Solanum tuberosum* L.) and considered as one of the most important root crop among small scale resource poor farmers (Terefe, 2003). More recently, cultivation of sweet potato is expanding to low lands of Ethiopia. It is an important crop during hunger periods in areas such as Wollaita, Sidama, Kanbata Tanbaro, Gamo Gofa and Hadiya zones in SNNPR from February to May. It is a short day plant which takes three to five months to mature depending on the variety. However, cold conditions in tropical highlands can extend the maturation period by 8 to 9 months (Geleta, 2009).

The exact time of introducing sweet potato to Ethiopia is not clearly known. However, the crop has become popular particularly in densely populated areas of the South, South-West and Eastern parts of the country and remained an important food source among the communities (Endale *et al.*, 1994). It is an important food crop and plays critical roles in rural diets. In some areas it ameliorates food shortage instances when crops like maize are in short supply and in time of drought. Southern Nation and Nationalities People Regions (SNNPR) is the leading producing region of sweet potato in Ethiopia. Studies have shown that the total area under sweet potato covers 23,643.84 hectares having annual production of 236,288.3 tones (CSA, 2002). Thus, sweet potatoes occupied 3% of the crop area and contributed to 16% of the regional total volume

of crop production (Endrias *et al.*, 2006). In SNNPR, particularly Wollaita zone, study has shown that sweet potato occupied 20% of cultivated area and accounted for 55% of the total volume of crop production. In the same zone particularly, in Boloso Sore Woreda, it covered 29% of cultivated area and contributed to 63% of total volume of crop production (Endrias *et al.*, 2006).

2.3. Overview of sweet potato varieties in Ethiopia

Different sweet potato cultivars are cultivated and consumed in Ethiopia. Among those cultivars white fleshed sweet potato cultivars are the predominant one in the country. Assefa *et al.* (2007) showed that among 70 million Ethiopian people white fleshed sweet potato variety is a staple food for 13 million people in the Southern Regional State of the country. When compared to orange fleshed sweet potato cultivar white sweet potato cultivar contains less or no pro-vitamin A content. However, higher dry matter content and less water content of the white fleshed varieties created more preference among consumers resulting in less consumption of the pro-vitamin-A rich orange fleshed varieties which is with high water content. The very hindering factor in the production and consumption of pro-vitamin-A rich variety in the country is its short supply, and those available ones are with less dry matter content, less storable and more susceptible to biotic and abiotic stresses (Assefa *et al.*, 2007).

Koka-12 and Guntute are the two orange fleshed sweet potato (OFSP) varieties that were released by Awassa Agricultural Research Center (AARC) from the local collection in 1987 based on their high yield which were 25.24 tons per hectare and 35.35 tons per hectare, respectively. Unfortunately, consumers did not accept them due to their flesh color (consumers are not familiar) and moist texture (content high water and low dry matter) and limited knowledge on the nutritional value of these varieties. Recently, however awareness created by consumers that these varieties contain high beta-carotinoid content and their richness in Vitamin-A a total of 97,000 cuttings of these varieties have been multiplied and distributed on the request of researchers, NGOs and farmers in Ethiopia (Assefa *et al.*, 2007).

Awassa Agricultural Research Center (2003) introduced 40 orange-fleshed sweet potato varieties that with high dry matter, low water content and high beta-carotene content from CIP-Kenya

based on consumer preference as shown in Table 2.1. Out of these 40 varieties 37 of them were distributed to different parts of sweet potato cultivation areas of Ethiopia (Assefa *et al.*, 2007).

Table 2.1 Orange-fleshed sweet potato varieties that have high dry matter and high beta-carotene content shipped to Ethiopia in September 2003

No	CIP No.	Origin	DM%	Skin color	Flesh color
1	999004.2	CIP breeding line	36	Red	Light orange
2	199005.11	CIP breeding line	26	Pink	Intermediate orange
3	199015.14	CIP breeding line	25	Yellow	Intermediate orange
4	199024.1	CIP breeding line	26	Cream	Light orange
5	199024.2	CIP breeding line	26	Red	Light orange
6	199026.1	CIP breeding line	26	Red	Light orange
7	199027.3	CIP breeding line	26	Red	Light orange
8	99034.1	CIP breeding line	34	Red	Dark orange
9	199062.1	CIP breeding line	31	Orange	Intermediate orange
10	440203	Korean cultivar	28	-	Light orange
11	440443	Chinese cultivar	28	Yellow	Light orange

Source: Assefa *et al.* (2007)

In addition to the above sweet potatoes, there are other cultivars released and cultivated in different parts of the country; some of these varieties shown in Table 2.2.

Table 2.2 Some sweet potato varieties released for production in Ethiopia

Variety	Skin color	Flesh color	Maturity days	Yield t/ha	Year of release	Breeder ARC
Kudade (TIS-1499)	Pink	Cream	90-120	24.08	1997	Awassa
Falaha (TIS-3912)	Pink	White	90-120	16.7	1997	Awassa
Bubo (I-144)	Cream	White	90-120	21.1	1987	Awassa
Guntute (AJAC-I)	Brownish orange	Deep orange	120-150	35.4	1997	Awassa
Bareda (375)	White	White	120-150	29.6	1997	Awassa
Domota	Brownish orange	Yellow	120-150	30.68	1997	Awassa
Awassa-83	Pink	Deep orange	150-180	36.6	1998	Awassa
Koka-12 (AJAC-I)	-	Deep orange	120-150	25.24	1987	Awassa
Koka-6	Cream	Pale yellow	90-120	18.33	2002	Awassa
192009-VII	White	White	90-120	17.62	2002	Awassa
Kulfo (Lo-323)	Cream	Orange	150	35.5	2004	Awassa
Kero	-	Pale orange	150	35.4	2004	Awassa
Tulla	-	Orange	150	28.5	2004	Awassa

Source: Personal communication: Areka Agricultural Research Center (ArARC)

Sweet potato plants, storage root skin and flesh color of three sweet potato cultivars collected from Areka which are used for current study shown in Figure 2.1a, b and c.

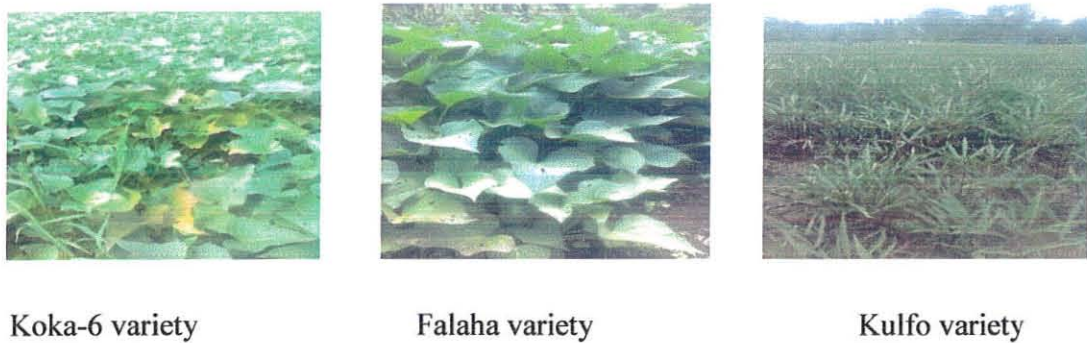


Figure 2.1a: Three sweet potato plants

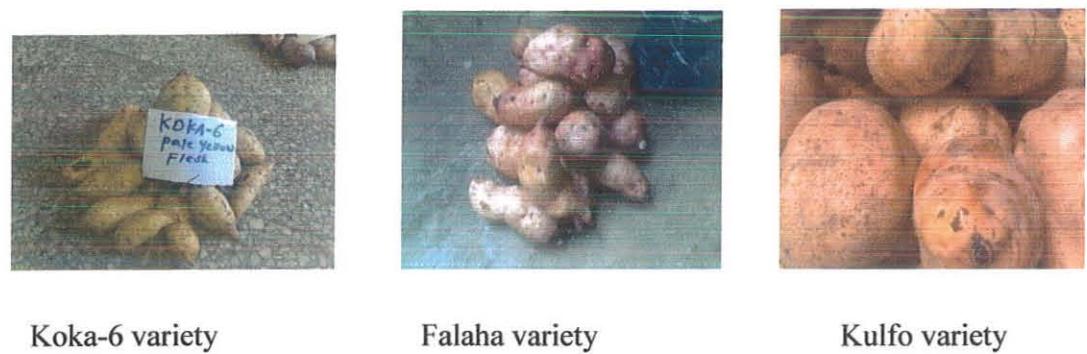


Figure 2.1b: Sweet potato varieties storage root skin colors

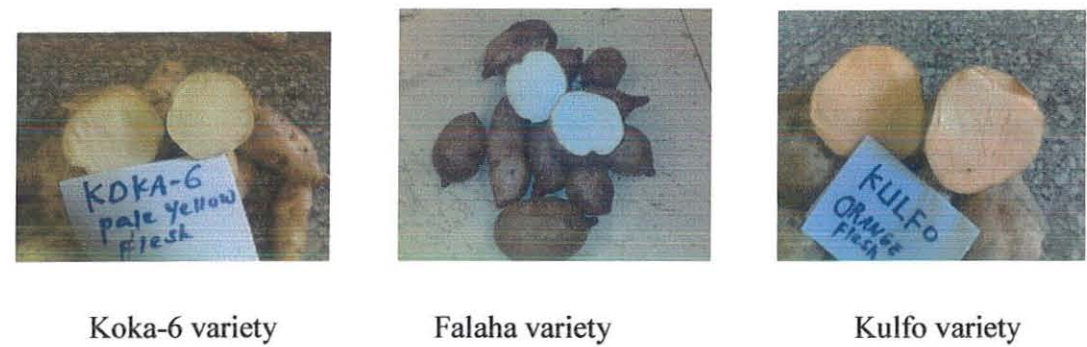


Figure 2.1c: Sweet potato varieties storage root flesh colors

(Photographs by author)

2.4. Nutritional composition of sweet potatoes

Root and tuber crops refer to any growing plant that stores edible material in subterranean root, corm or tuber. They form a major staple food group in most developing countries of Africa, Asia and Latin America. The most popular of this food group are cassava, yam, cocoyam, Irish and sweet potatoes. The nutritional values of those crops are poor sources of some major nutrients but they are the cheapest sources of dietary energy in the form of carbohydrates in developing countries. The energy value of these crops is about one third of that of an equivalent weight of grain such as rice or wheat because tubers have high water content. However, the high yields of most root crops ensure an energy output per hectare per day which is considerably higher than that of grains. It is often assumed that root and tuber crops have a poor nutritive value because the comparison of their nutrient content to other crops is usually made on a fresh weight basis as expressed in composition tables (Serge, 1996; Ugwu, 2009).

Sweet potato is a staple food source for many indigenous populations in China, Central and South Americas, Ryukyu Islands, Africa, Caribbean, Maori people, Hawaiians and Papua New Guineans. It serves as an important protein source for many world populations and is an important source of starch and other carbohydrates. The energy value of sweet potato exceeds that of potato, cassava and other known tubers (ENV/JM/MONO, 2010). As with all crops the nutritional composition of roots and tubers varies from place to place depending on the climate, soil, the crop variety and other factors (Woolfe, 1987 as cited in Ugwu, 2009). Among these crops the nutritional composition of sweet potato is discussed below.

2.4.1. Proximate composition of sweet potatoes

The main economic parts of all sweet potato plants are the storage root, stem and the leaves. Both the root and the leaf parts of sweet potato can be used as food for humans and animals. The chemical composition of these parts is quite different. The proximate composition of raw sweet potato storage root with and without skin is shown in Table 2.3. The roots have high moisture content and low dry matter and protein content than leaves. The average dry matter content of the root is approximately 30% but varies depending on variety, climate and harvesting time (Le, 2004). Dried sweet potato leaves consist of 22% crude protein, 46% crude fiber, and 9% total ash (ENV/JM/MONO, 2010).

In Nigeria, sweet potatoes root contained 70.57% moisture, 29.43% dry matter, 10.65% protein, 2.69% fat, 3.28% ash and 83.37% total carbohydrate (Odebunmi *et al.*, 2007). In the same country the nutritional composition studies on four sweet potato varieties (two white and two orange fleshed) indicated variation in chemical content from variety to variety to different levels of nitrogen fertilizer application. They obtained the ranges of values for chemical composition such as dry matter, moisture, crude protein, total ash, crude fiber and crude fat contents were (30-39), (61-70), (3.28-5.47), (1.40-1.70), (2.30-2.8) and (1.20-1.40)%, respectively. The ranges of values for mineral contents such as phosphorus, calcium and magnesium were (20-27), (40-90) and (12.20-30.40) mg/100g, respectively (Ukom *et al.*, 2009). Their test results showed nitrogen fertilizer application improved the β -carotene and protein contents of most varieties at 40-80 KgN/ha while the control (no nitrogen fertilizer) was associated with the highest crude fiber values. They concluded that the variability in the β -carotene and chemical composition of the various varieties of sweet potato can be useful in directing sweet potato research production and consumption with the view to increasing nutritional (provitamin A and protein) status of the consumers.

Ingabire and Hilda (2011) in their study compared the nutritional composition of selected two yellow sweet potato varieties (Kwizekumwe, 440170) and two white sweet potato varieties (Mugande and Rutambira 4-160) cultivated in Rwanda in order to determine high nutritional variety. The study revealed that the moisture content in all sweet potato varieties was quite high and varied (62.58 to 64.34) from variety to variety due to the difference in the genetic composition and also the agro cultural practices. The crude protein (0.91), total reducing sugar (2.50), crude ash (0.44) content was high in Kwizekumwe variety. B-carotene content was present only in the yellow varieties but was found to be high in Kwizekumwe (1.85). On the other hand yellow (440170) variety recorded the highest in crude fiber (0.14) and all the results were reported in fresh weight basis. From test results they concluded that among four sweet potato varieties the yellow (Kwizekumwe) variety was found to be more nutritious when compared to the other varieties.

Table 2.3 Proximate (g/100g) and mineral (mg/100g) composition of raw sweet potato root with and without skin

Composition	With skin	Without skin
Water (fresh weight)	77.3	66.1-74.9
Protein	6.9	3.5-6.8
Total Fat	0.2	0.6-0.7
Ash	4.4	2.6-4.0
Carbohydrate	88.6	88.5-95.0
Dietary Fiber	13.2	6.5
Calcium	132.0	79.0-147.4
Iron	2.7	2.1-6.4
Magnesium	110.0	73.7-87.6
Phosphorus	206.0	135.7-179.2
Potassium	1483.3	724.0-1453.6
Sodium	242.1	11.8-107.0
Zink	1.3	0.6-1.2
Manganese	1.1	1.3-2.6

Source: ENV/JM/MONO (2010)

Depending on the varieties and other factors there has been wider range of nutritional values and antinutritional factors of sweet potato cultivars that have been reported by different researchers. In order to get full information, some of the research works on the nutritional values of sweet potatoes are briefly discussed below.

2.4.1.1. Dry matter content

The roots of sweet potato have a high moisture and low dry matter content. The average dry matter content is approximately 30% but varies depending on genetic selection, water balance at harvest condition and time of storage and other internal physiological factors (Le, 2004; Purcell *et al.*, 1989). Depending on varieties sweet potato storage root contains 17.9 to 49.3% dry matter. The dry matter composition of the sweet potato varieties is varying in different location. For example 16 cultivars suitable for North Carolina growing conditions and quality demands were found to contain 23.7 to 28.6% dry matter, 13 high yielding clones in West New Guinea were found to contain 22.8 to 30.79% and dry matter in 6 selections of Ugandan sweet potato varieties were ranged from 30.3 to 39.2%. It has been demonstrated that soil moisture levels during the

growth season significantly influence root dry matter content. Available soil moisture levels above 25% caused decreases in dry matter (Purcell *et al.*, 1989).

2.4.1.2. Carbohydrate composition

Sweet potato is one of the world's most important food crops. Its main importance as food has been the carbohydrate content or starch source as a dietary staple (Collins and Walter, 1982). Most of the dry matter (85 to 90%) of the sweet potato is carbohydrate. The carbohydrate composition consists of starch, sugars, pectin, cellulose and probably hemicelluloses and pentose. Sweet potato starch, which contains 79 to 83% amylopectin, is the major carbohydrate and accounts for 65 to 80% of the total dry matter. Although maltose has been reported in raw Centennial sweet potatoes, others have demonstrated that maltose is not present in raw tissue but is formed when roots are ground with hot solvent. Raw sweet potato roots contain 0.33% glucose, 0.15% fructose, 3.47% sucrose. Sucrose is thus the most abundant sugar in the raw sweet potato root, ranging from 2.5 to 5.2% in freshly harvested. Glucose and fructose are minor constituents of raw sweet potato roots. Factors affecting the total carbohydrate composition are essentially the same as those that influence dry matter content (Purcell *et al.*, 1989).

2.4.1.3. Crude fiber content

Crude fiber has many desirable functional properties. It can reduce caloric uptake and provide health benefits concerned to the incidence of chronic diseases such as colonic cancer, diabetes, heart diseases and certain digestive diseases (Wanda and Walter, 1989). The fiber content of sweet potatoes has been reported to range from 2.5 to 5% dry basis. The only report available lists cellulose content of sweet potatoes at 2.69% dry basis. The fiber fraction of sweet potato consists of the cellulose and possibly hemicelluloses and pentose (Purcell *et al.*, 1989).

2.4.1.4. Protein content

It is often assumed that sweet potatoes are a starchy food without significant amounts of protein content. However, a number of animal feeding studies indicated that sweet potatoes contain nearly equal amount of protein content to corn on the dry weight basis. The protein value of sweet potato has also been recognized for human nutrition (Purcell *et al.*, 1989).

The protein level of sweet potatoes is ranged from 1.73 to 11.8% on dry weight basis due to various factors. These factors are cultivar of genetic selection, the time between planting and harvesting, nitrogen and water balance and location at which the sweet potatoes are grown. For example, Jewel sweet potato was produced 4.13% of protein in one location in North Carolina while the same cultivar was produced 8.81% of protein in a different location in North Carolina in the same year. Centennial and Jewel sweet potatoes grown in North Carolina had twice as much as protein content as the same cultivars from the same root maintenance collection grown in Laguna, Philippines. These differences of protein content within a cultivar may be a complex function of soil water and soil nitrogen levels (Purcell *et al.*, 1989).

On other hand, studies by Collins and Walter (1989) indicated that the crude protein content of sweet potato varieties ranging from 1.3% to 10% in dry weight basis. This variation in sweet potato protein content was due to production practices, environmental conditions and genetic factors. The protein content of sweet potato is not evenly distributed throughout the root. The crude protein content is slightly higher at the stem end than the root ending and much higher the outer layer part of the root (William *et al.*, 1984). Thus care should be taken during sample preparation in order to include all parts of sweet potato root in protein amount determination.

2.4.1.5. Fat content

Sweet potato cultivars contain relatively low amount of lipids compared to other nutrients. The average reported value of lipid levels in sweet potato varieties was ranged from 0.29% to 2.7% dry weight basis (Purcell *et al.*, 1989). Study which deal the changes of lipid in nine varieties of sweet potatoes during storage has been shown that the total lipid amounts of these varieties was ranged from 1.24% to 2.50 % dry weight basis (Boggess *et al.*, 1971).

2.4.1.6. Gross energy

Proximate analysis on root crops in the diets of growing pigs has been shown that fodder beet and sweet potato roots have high levels of carbohydrate but low levels of crude protein. The principal use of these starchy root and tuber crops as human food and animal feed is ,therefore, as a source of dietary energy yielding ingredients and their value will depend on the availability of that energy and the efficiency with which it can be utilized (Philip, 1991).

2.4.2. Mineral composition of sweet potatoes

The mineral content of sweet potatoes had been measured by several researches (Woolfe, 1992; Suda *et al.*, 1999; Antia *et al.*, 2006). Sweet potato contains substantial quantities of vitamin C, moderate quantities of thiamin (vitamin B1), riboflavin (vitamin B2) and niacin, some quantities of panthothenic acid (vitamin B5), pyridoxine (vitamin B6), folic acid and satisfactory quantities of vitamin E are present. It also contains some essential minerals and trace elements having especially high quantities of iron. Two other important minerals present are potassium and calcium (Woolfe, 1992). Moderate quantities of zinc, sodium, magnesium and manganese are also present (Antia *et al.*, 2006; Suda *et al.*, 1999).

Elkins (1979) and Lopez *et al.* (1980) reported that depending on the varieties, raw sweet potato roots were a good source of minerals including iron (0.85-9.59 mg/100g), calcium (17.4-32.7mg/100g), sodium (8.0-30.3mg/100g), magnesium (18.3-22.2mg/100g), phosphorus (39.2-48.9mg/100g) and an excellent source of potassium (228-360mg/100g). The roots were also a fair source of other essential minerals such as zinc (0.26-0.27mg/100g), copper (0.13-0.25mg/100g) all the amounts were on dry weight basis. In other studies the mineral value of raw sweet potatoes reported were; potassium (594.9mg/100g), calcium(78.6mg/100g), phosphorus (115.4 mg/100g) and iron (1.72mg/100g) of dry matter (Purcell *et al.*, 1989). Mineral compositions of raw sweet potatoes root with and without skin are shown in Table 2.3.

2.4.3. Antinutritional factors

Plants are the major sources of nutrients to peoples of the developing world. However, present of antinutritional factors limit their optimal utilization (Hassan *et al.*, 2011). These compounds which affect the digestion system and availability of the nutrients to the body are often referred to as antinutritional factors. Among potential plant toxins and antinutritional factors both sweet potato root and leaf contain antinutrients such as phytate, oxalate and tannin (Olayiwola *et al.*, 2009; Eluagu and Onimawo, 2010).

2.4.3.1. Phytate

Phytates (salts of phytic acid), which are also known as inositol hexakisphosphates (InsP6) are naturally occurring phosphorus compounds significantly influence the functional and nutritional

properties of foods. They are regarded as the primary storage form of both phosphate and inositol in plant seeds and grains (Shashi *et al.*, 2007).

The presence of phytate in foods has been associated with reduced mineral absorption due to the structure of phytate which has high density of negatively charged phosphate groups which form very stable complexes with mineral ions causing non-availability for intestinal absorption of animals and humans (Weaver, 2002). Phytic acid binds trace and macro-elements such as calcium, magnesium, zinc and iron in the gastrointestinal tract are making dietary minerals unavailable for and utilization by the body due to its ability to form insoluble salts with their ions. The binding of divalent cations by phytate in vitro had been shown by their relative affinities to be in the order of $\text{Cu}^{+2} > \text{Zn}^{+2} > \text{Co}^{+2} > \text{Mn}^{+2} > \text{Mg}^{+2} > \text{Fe}^{+2} > \text{Ca}^{+2}$ (Chan, 1988 and Ramakrishna *et al.*, 2006). However, the bioavailability of these minerals in the human body can be determined by measuring the molar ratio of phytate/ minerals in the food and diet. The suggested critical values for the inhibitory effect of phytate on the bioavailability of minerals: phytate/iron >1 , phytate/zinc >15 , phytate/calcium >0.24 and phytate $\times$ calcium/zinc >200 (Norhaizan and Faizadatul, 2009).

Consumption of phytate on the other hand has some positive effects on human health. Phytic acid acts as an antioxidant and anti-carcinogen (Jenab and Thompson, 2002). It has the potential ability to lower blood glucose, reduce cholesterol and the risks of colon cancer and heart disease (Greiner and Konietzny, 2006; Chan, 1988).

Phytate is an abundant plant constituent; comprising 0.1-3% of the dry weight of many roots, tubers, fruits, nuts, cereals, legumes, oil seeds, spores and pollen, 4.8% of Waldron wheat bran and as high as 6.4 % of corn germ (Chan,1988). As many other root and cereals crops, sweet potato contains a significant amount of phytate. Dilworth *et al.* (2005) cited in ENV/JM/MONO (2010) had been reported that the level of phytate value was 4.98×10^3 mmole/g and 2.238×10^3 mmole/g in uncooked and cooked sweet potato roots, respectively.

2.4.3.2. Oxalate

Oxalate is a salt formed from oxalic acid with various metals such as calcium, magnesium, sodium and potassium. Some oxalate salts such as sodium and potassium are soluble whereas

calcium oxalate salts are insoluble. The insoluble calcium oxalate has the tendency to precipitate in the kidneys or in the urinary tract thus forming sharp-edged calcium oxalate crystals when the levels are high enough. These crystals play a role to the formation of kidney stone formation in the urinary tract when the acid is excreted in the urine (Noonan and Savage, 1999). Oxalate like phytate binds minerals such as calcium and magnesium and interfere with their metabolism. They cause muscular weakness and paralysis. Oxalates also cause gastrointestinal tract irritation, blockage of the renal tubules by calcium oxalate crystals, development of urinary calculi and hypocalcaemia and cause nephritic lesions in the kidney. Too much of soluble oxalate in the body prevents the absorption of soluble calcium ions as the oxalate binds the calcium ions to form insoluble calcium oxalate complexes. As a result of this, people with the tendency to form kidney stones are advised to avoid oxalate-rich foods (Soetan and Oyewole, 2009). When oxalic acid is consumed, it irritates the lining of the gut and can prove fatal in large doses. Currently, patients are advised to limit their intake of foods with a total intake of oxalate not exceeding 50–60 mg per day (Massey *et al.*, 2001).

The distribution of oxalate within plant parts is uneven; For example, 73-89mg/100g of oxalate value was reported in uncooked sweet potato leaves by Antia *et al.* (2006). Proper boiling of sweet potato leaves before consumption significantly reduces the total oxalate content (Antia *et al.*, 2006) since more than 60% of oxalates are present in water soluble form which leaches out into the water. Oxalates both free and calcium oxalate are present in the roots of sweet potatoes and the total levels are generally similar to those in other root crops (Woolfe, 1992).

2.4.3.3. Tannin

Tannin is phenolic compounds responsible for the bitterness and astringency (due to their high polyphenol content) of many foods and beverages (Ramakrishna *et al.*, 2006). It also causes browning or other pigmentation problems in fresh foods and processed products and acts as anti nutritional factor by provoking astringent reaction in the mouth, thereby rendering the food unpalatable (Eluagu and Onimawo, 2010).

The two distinctive groups are the hydrolysable tannins (they may be readily hydrolyzed into a mixture of carbohydrates and phenols) and condensed tannins which are complex flavonoids polymers. Tannins form insoluble enzyme-resistant complexes with proteins, carbohydrates and

lipids leading to a reduction in digestibility of these nutrients. Other nutritional effects that have been attributed to tannins include damage to the intestinal tract, toxicity of tannins absorbed from the gut interference with the absorption of iron, zinc and a possible carcinogenic effect. They also cause decreased palatability and reduced growth rate (Soetan and Oyewole, 2009; Eluagu and Onimawo, 2010).

The beneficial or antinutritional properties of tannins depend on their chemical structure and amount in the diet. The total acceptable tannin daily intake for a man is 560 mg (Anonymous, 1973). Study by Schiavone *et al.* (2008) had been showed that products containing chestnut tannins included at low dosages (0.15-0.2 %) in the diet can be beneficial. Like other crops sweet potatoes contain different amount of polyphenolic compounds. These compounds are phenolic acids (chlorogenic-acid, caffeic-acid and dicaffeoylquinic acid), anthocyanins (cyanidin and peonidin which cause the purple color found in some sweet potato varieties) and flavonoids (quercetin, $C_{15}H_{10}O_7$, which cause the yellow color found in some sweet potato varieties and rutin) (Guan *et al.*, 2006).

2.5. Use of composite flour in food production

Composite flour is a mixture of wheat and non wheat flours or wholly non wheat flour prepared from mixtures of flours from cereals, roots, tubers, legumes or other raw materials (David, 1992). The use of composite flour is advantageous for developing countries as it promotes high yielding native plant species, increases protein for human nutrition and enhances domestic agriculture production. The goal of earlier researcher with composite flours was to save the largest possible percentage of wheat flour in the production of certain baked products. The extent to which wheat flour could be replaced by other vegetable flours naturally depends on the nature of products to be baked (Jolaosho, 2010).

Different researchers have been made bakery products from wheat flour and other crop flours in varying blend ratios. Fang (2008) had been studied the physico-chemical and organoleptic attributes of wheat bread substituted with four different percentages (control, 5%, 10% and 15%) of pumpkin flour. Bread substitution from 5-15% level was increased the ash and crude fiber content while the protein and fat content were decreased and pumpkin flour showed higher water holding capacity than wheat flour. The mineral (Ca, Na, K, Fe, P and Mg) contents were

increased with increased percentages of pumpkin flour in the bread. Texture result showed that the 10% and 15% pumpkin flour bread was significantly different ($p < 0.05$) in terms of hardness, gumminess and elasticity values than the control. The gluten content of control and 5% dough was more compared to the 10-15% pumpkin flour dough. Sensory evaluation indicated that the 5% pumpkin flour bread was the most acceptable.

The bread making potential of lesser yam (*Dioscorea esculenta*) and wheat composite flour in varying substitute level was studied by evaluating the sensory, specific loaf volume, proximate, selected functional properties and paste characteristics of bread in Nigeria (Ukpabi, 2010). The result showed that bread produced with 20% yam inclusion had 87% specific loaf volume of the control sample and was not significantly scored lower than the sole wheat bread in overall acceptability, taste, appearance and softness by the sensory assessors.

In another research, the use of taro flour substitution in wheat flour from 0 to 20% for the production of Egyptian bread was evaluated for attributes such as farinograph, extensograph properties of the produced dough, organoleptic properties and chemical composition of the produced bread (Ammar *et al.*, 2009). The Farinograph results showed that increase of substitution level increase the water absorption and dough weakening but decrease the mixing time and dough stability while the results of extensograph showed that dough energy, resistance to extension and proportional number decreased with increasing the taro flour level in the flour blends. The organoleptic evaluation showed that substitution of wheat flour with taro flour up to 10% produce bread similar to the control (wheat bread) in all the organoleptic properties. The increase of the taro flour level resulted in decreasing in crude protein and ether extract while ash, total carbohydrates and fiber contents increased. Generally, they concluded that substitution of wheat flour with taro flour in bread making with substitution level up to 10% produce bread with rheological and organoleptic properties similar to the wheat flour bread.

The feasibility of partially replacing wheat flour with plantain flour in bread and biscuit making were investigated by (Mepba *et al.*, 2007). The result indicated that no significant difference was observed in the nutrient contents of control (wheat bread) and composite bread at 5% level of plantain addition. Water and oil absorption capacities of composite flours increased with increasing levels of plantain flour in the blend. As the plantain flour content of the composite dough increased beyond 5%, alveograph values for dough resistance to extension, extensibility

and mechanical work of dough deformation decreased. The oven spring and specific loaf volume decreased significantly with increased plantain content of blends. Sensory panel rating of the 10% plantain flour content of composite bread was not significantly different from the 5% level of wheat flour substitution but was significantly different from the control (wheat bread). The flow and break strength of wheat-plantain composite biscuits decreased with increasing dilution of wheat with plantain flour. The mean scores for color, taste and crispness/aroma were generally high for all biscuits samples containing 0-70% plantain flour on a 9-point hedonic scale. They concluded that organoleptically acceptable breads and biscuits were formulated from wheat-plantain composite flours using up to 80:20% and 60:40% ratios of wheat-plantain flour as maximum acceptable levels of substitution for breads and biscuits, respectively.

The effects of Flaxseed (*Linum usitatissimum*) flour on the baking properties of cakes and cookies had been studied by Shoukat *et al.* (2006) 100% wheat flour up to 25% substitution levels of flaxseed in wheat flour. The result showed that the percentage values of moisture, ash, fat and protein of both cookies and cakes increased as the amount of linseed flour increased in the composite flour. The average thickness and width of cookies increased as the amount of linseed in composite flour was increased but spread factor was decreased. The overall volume of cakes decreased as the amount of linseed was increased. Both cookies and cakes were analyzed for different sensory attributes like color, texture, taste, flavor and overall acceptability. Based on these findings they concluded that small to moderate inclusion levels of linseed, especially in the range of 10 to 20% result in favorable baked products. In addition, they concluded that products prepared with flaxseed not only taste great but also provide enormous health benefits therefore it is highly recommended that this potential important seed must be used extensively in baking industry to provide value added products to consumer.

2.6. Value added products from sweet potato

Studies have been presented that sweet potato purees and powders can be used as thickening and gelling agents to impart desired textural properties and enhance the nutritional values, antioxidant activity as well as natural color (e.g. orange and purple) of numerous food products. These ingredients from sweet potatoes can be used as alternatives to wheat products for individuals diagnosed with celiac disease and incorporated in low glycemic index foods for diabetics (Truong and Ramesh, 2010).

In Nigeria, infant weaning foods have been made from sweet potato based products (sweet potato, cowpea and peanut) that is similar in sensory characteristics of the commercial baby food (control) and contains higher amount of protein, ash and moisture. This sweet potato based products prepared to enhance nutritional values of the infant foods (Adenuga, 2010).

Sukhcharn *et al.* (2008) had been studied the effect of incorporating sweet potato flour to wheat flour on the quality characteristics of cookies. Water absorption increases from 29 to 169% with increasing the proportion of sweet potato flour. The cohesiveness of dough with 20% sweet potato flour and 80% of wheat flour increased to 0.480g/s and then decreased with increasing percentage of sweet potato flour. Sweet potato flour lowered the spread factor from 6.666 to 6.150 with increasing its level from 0-100%. Sensory evaluation revealed that increasing levels of sweet potato flour (60%) lowered the overall acceptability because of taste and distinct flavor developed during baking.

It is noted that blending of sweet potato flour with wheat flour up to 20% level produced samples which can be used for production of bakery goods with improved functional properties and reduced retro-gradation, staling rate and production time (Adeleke and Odedeji, 2010). Increase in sweet potato flour increases moisture, emulsion capacity but decreases water absorption capacity, fat absorption capacity, foaming capacity, bulk density and viscosity of sweet potato-wheat flour blends.

2.7. Use of sweet potato flour in bread making

Greene and Bovell-Benjamin (2004) have been studied the macroscopic and sensory evaluation of bread supplemented with 50% up to 65% sweet potato flour. They concluded that moisture contents of the breads fluctuated during storage. Protein value and loaf volume were highest for the bread supplemented with 50% sweet potato flour and b-carotene contents was highest in the breads supplemented with 65% sweet potato flour. Carbohydrate contents increases with increasing sweet potato flour. Sweet potato flour could be used to substitute whole wheat flour at 50%, 55%, 60% and 65% levels in bread making. However, certain attributes such as the wheaty taste and smell, cell size, grittiness and denseness of the sweet potato breads were different from the commercial 100% whole wheat bread.

Another research showed that sweet potato flour can be substituted with wheat flour to make breads for improved nutritional quality and reduced cost in the production of bread in Nigeria (Ifie, 2011). Addition of sweet potato flour slight decrease in the protein and fat content and increases the ash, carbohydrate and crude fiber content of the product. Sweet potato flour also enhances the energy, Vitamin A, B6, C and magnesium contents of the product. In this study no significant differences were observed between whole wheat bread and the sweet potato supplemented bread in sensory attributes of aroma, texture, taste and overall acceptability. However, in terms of product color the 25% sweet potato supplemented bread sample had the highest consumer acceptance.

The acceptability of bread produced from Hausa-potato and sweet potato composite flours at different substitution levels with wheat flour have been studied by (Aniedu and Agugo, 2010). In proximate analysis 10-30% Hausa-potato and sweet potato flour substitution increases crude fiber, ether extract and ash of the products. Higher fiber content was observed in Hausa potato bread samples with the 30% substitution level. On other hand, highest protein was observed when wheat flour bread sample was used whereas the protein amount decreased as substitution level increased. Color, taste, texture and general acceptability of all bread samples were similar at 10% substitution levels in all the sensory attributes. However, it was observed that sweet potato flour could act as a coloring agent in bread production.

Hamed *et al.* (1973) had been studied the effect of adding sweet potato flour to wheat flour on physical dough properties and baking conditions. In farinograph study; additions of all sweet potato flours increased absorption weakened the dough and decreased dough development, dough stability and valorimeter index. Bread weight increased and its volume decreased when sweet potato flour was added to wheat flour. In addition, they concluded that for countries that having suitable conditions for sweet potato growth and a shortage of wheat addition of sweet potato flour to wheat flour for bread making will decrease the amount of wheat imported and will be of economic advantage.

The effects of sweet potato pastes supplemented with wheat flour on physicochemical properties of dough and bread were investigated by (Kun-Lun *et al.*, 2009). Farinograph absorption and mixing time all decreased as the addition of sweet potato paste increased. In addition, alveograph results such as tenacity, extensibility and deformation energy decreased with the increased sweet

potato paste. Loaf volume slightly decreased with addition of more than 20% of sweet potato paste but 10% of sweet potato paste could be added in dough without decreasing dough expansion and volume of bread sample. It is noted that bread supplemented with sweet potato paste scored more favorable than that of the control by consumers.

2.8. Nutritional value of bread and its ingredients

Bread is a food product that is universally accepted as a very convenient form of food that has desirability to all population rich and poor, rural and urban. It is a good source of nutrients such as macronutrients (carbohydrates, protein and fat) and micronutrients (minerals and vitamins) that are all essential for human health. These characteristics lead all countries throughout the world to study the chemical composition of the bread that consumed to improve its nutritive value (Mohammed *et al.*, 2008). In addition, continuous improvement in baking technology and introduction of new materials and ingredients to the bread composition resulted in better quality product formulation which enhance its nutritional value.

It is important to notice that the nutritional value of bread is depends on chemical composition of bread (ingredients) and baking methods. Nutritional value of pan and balady bread made of whole wheat flour and with flour of 72% extraction rate was determined by (Alian *et al.*, 1997 as cited in Mohammed *et al.*, 2008). They concluded in their results that balady bread made from whole wheat flour contains moisture (33-34%), protein (11.8-11.9%), fat (2.53-2.55%), crude fiber (3.62-3.93%), ash (2.63-2.98%) and carbohydrate (78.91-78.98%) and minerals in the range of (3.5-4.1mg/100g) Mn, (167-1751mg/100g) Mg, (2.20-3.041mg/100g) Zinc, (0.49-0.561mg/100g) Cu, (30-321mg/100g) Ca and (310-3401mg/100g) phosphorus. But these nutrients obtained for the same bread made from white wheat flour of 72% extraction were on the range of (32-33%) moisture, (11.58-11.65%) protein, (1.4-1.6%) fat, (0.87-0.95%) crude fiber, (1.67-1.81%) ash and (84.1-84.2%) carbohydrates and minerals were on the range of (2.25-2.51mg/100g) Mn, (126-1421mg/100g) Mg, (1.58-2.101mg/100g) Zinc, (0.42-0.421mg/100g) Cu, (21-221mg/100g) Ca and (190-2201mg/100g) phosphorus.

In case of pan bread is concerned, the same investigators reported that, this kind of bread made from whole wheat flour had moisture content ranged from (25.5-24.7%), protein (11.78-11.91%), fat (3.56-3.61%) crude fiber (3.58-3.82%), ash (1.95-2.38%) and carbohydrate (78.65-

78.74%) and minerals were on the range (2.89-3.041mg/100g) of Mn, (110-1301mg/100g) of Mg, (2.4-3.91mg/100g) of Zn, (0.4-0.61mg/100g) of Cu, (22-251mg/100g) of Ca and (298-3101mg/100g) of phosphorus. However, these nutrients evaluated for the same bread from white wheat flour of 72% extraction were on the range of (24.1-24.69%) moisture, (11.55-11.62%) protein, (2.35-2.49%) fat, (0.89-1.29%) ash and (83.7-83.9%) carbohydrates and minerals were on the range of (1.93-2.071mg/100g) Mn, (110-1051mg/100g) Mg, (2.10-2.721mg/100g) Zn, (0.25-0.31mg/100g) Cu, (15-191mg/100g) Ca, (185-1961mg/100g) phosphorus (Alian *et al.*, 1997 as cited in Mohammed *et al.*, 2008).

2.9. Functional ingredients in bread baking

Bread quality is determined by the complex interactions of the raw materials, their qualities and quantities used in the bread formulation and the processing method used (Mardiana, 2008). Hence, during bread production the baker should start with an understanding of the function of ingredients in quality control of the bread. Using good technical skills, the baker can manipulate the inconsistencies of ingredients to produce a uniform, consistent product.

The basic ingredients in a typical bread making are flour, water, salt and yeasts. However, in modern bread making a large number of other ingredients and additives such as yeast food, sugar, improvers, milk, egg, shortening (fat), emulsifiers, antifungal agents, antioxidants, enzymes, flavoring and enriching ingredients can be used (Nduka, 1987). Functions of common ingredients used in bread making are discussed below.

2.9.1. Flour

Flour is a fine powder commonly made from wheat but also from maize, rye, barley and rice among many other grasses and non-grain plants. It is the major basic ingredient in bakery products. Due to its important characteristics, wheat flour is the main ingredient in most types of breads. When wheat flour is mixed with water a complex protein called gluten is formed. During interaction the developed gluten gives wheat dough an elastic structure that allows it to be worked in a variety of ways and which allows the retention of gas bubbles in an intact structure resulting in a sponge-like texture to the final product. This is highly desired for breads, cakes and other baked products (Aboaba and Obakpolor, 2010). Thus, end products are determined by the type of wheat flour especially protein and gluten content of the flour. For example, the harder the

wheat the higher the protein content and the softer the wheat the lower the protein content in the flour. Soft low protein wheat is used in cakes, pastries, cookies, crackers and oriental noodles. On other hand, hard high protein (9% to 15%) wheat is used in breads (Mardiana, 2008).

2.9.2. Water

In bread formulation water is the second main ingredient on the amount and the least expensive ingredient so the control of its amount is important for quality attributes of final products. The main function of water is hydration of component ingredients during dough formulation. It is vital throughout the bread making processes for dissolution of salt and sugar, assisting the dispersion of yeast cell, starch and sucrose hydrolysis, activation of enzymes to form new bonds between the macromolecules in the flour and consequently alters the rheological properties of the dough. All ingredients must have water to function. Insufficient water addition to the flour resulted in inadequate cohesiveness of the dough, which is unable to sustain mechanical stresses. Conversely, excessive amount of water added to the flour resulted in weak and sticky dough or dilute a good product (Jolaosho, 2010). Thus all ingredients must have proper amount of water to perform their function.

2.9.3. Yeast

Yeast is also basic ingredient in bread formulation. Its role in bread making are crucial by acting as a leavening agent, strengthen and developing gluten in dough and contributing to the flavor generation in the bread. It converts fermentable sugars into carbon dioxide and alcohol during dough fermentation. Among yeast species, *Saccharomyces cerevisiae* is the most common yeast species used in bread making (Mardiana, 2008 and Jolaosho, 2010). Yeast is a living organism and its function can be influenced by storage practices and other actions. Bakers' yeast is available in different forms including compressed, granular, cream, dried pellet, instant, encapsulated and frozen. For example, dry yeasts have a longer shelf life and do not need to be refrigerated while compressed and cream yeasts need to be stored at refrigerated conditions. Active dry yeast must be pre hydrated in 5 to 15 minutes before adding to dough in water while instant dry yeast can be added without pre hydrating. The amount of yeast needed during bread making varies from beaker to beaker however; the level of usage in most bread is 2 to 5% compressed yeast (Jolaosho, 2010).

2.9.4. Salt

Salt is another basic ingredient in bread formulation. The primary function of salt (sodium chloride) is to give good flavor of the baked products. Salt regulates dough fermentation with a partial dehydration of the yeast cell in the time of dough making. It also toughens the gluten and strengthens weaker flours. The amount of salt needed during bread making varies from beaker to beaker but proper amount is important in order to obtain quality bread. Too little salt enhances the dough to ferment fast while too much salt slows down the fermentation process. The level of usage in most bread is in the range 1.5-2.5% of total flour weight (Jolaosho, 2010).

2.9.5. Improvers

The use of improvers in bread making has been practiced to improve dough handling properties, increase the quality of fresh breads and extend the shelf life of stored bread. Improvers are added to improve dough strength which results in higher loaf volume and better crumb texture. Improvers in the bread formulation may contain one or combination with other ingredients depending on the functionality of the additive in the bread making (Mardiana, 2008).

3. Materials and Methods

3.1. Description of the sampling area

Areka Agricultural Center is found in Boloso Sore district, Wollaita Zone of Southern Nations, Nationalities and People's Region (SNNPR). Boloso Sore Woreda is bordered on the North by Kembata Tembaro Zone, on the South by Damot Sore Woreda, on the West by Boloso Bombe Woreda and on the East by Damot Pulasa Woreda. Areka is located 320 kilometers South of Addis Ababa and 30 kilometers away from the zonal capital city, Soddo.

According to the census report of Ethiopian Central Statistical Agency (2007), the population of Boloso Sore Woreda has 177,703, with an estimated total area of 336 square kilometers. Administratively this woreda has 26 kebeles. This woreda has two Agro-Economic Zone. These are Woina Dega with 86.4 meter altitude above sea level and Kola with 13.6 meter altitude above sea level. The Astronomical location is 6° - 7° latitude and 378° longitude. The area is located at an altitude range of 1730 and 1830 meters above sea level. The area like most parts of the country has two periods of rainfall; the "big" and "small" rains of June to September and March to April, respectively, receiving an average annual rainfall of about 1528.1mm. The average annual temperature is 19.5°C and the yearly maximum and minimum temperature is about 25.6°C and 13.7°C , respectively.

The population is predominantly Wollaita and agriculture is the main source of income in the area, where the farming system is characterized by small scale production of mixed crop cultivation and rearing of livestock. The food crops cultivated in this area are tuber and root crops (enset, taro, sweet potato, yam, and cassava), Cereals (teff, wheat, maize, sorghum and barley), pulses (beans, peas and nug), fruits (banana, avocados, mango, orange, pumpkin, papaya etc), different vegetables and spices and stimulants (coffee, chat, ginger and pepper). From the dietary information, the major staple diets are maize and enset followed by sweet potato and a combination of the above crops. Cattle, sheep, goat, chicken and donkeys are common livestock production in the area (Boloso Sore Woreda Socio Economic, 2003).

3.2. Selection of sampling site and sampling method

Sampling site

Three sweet potato varieties with orange, yellow and white flesh colors were collected from Areka (Areka Agricultural Research Center). Wheat flour was obtained from KOJJ Food Processing Complex P.L.C. currently used for bread production. The other ingredients such as compressed yeast, powdered salt (NaCl) and improver were purchased from the local market in Addis Ababa. In Wollaita Zone, Areka was chosen for this study for reasons of accessibility and potential area of sweet potato varieties produced and consumed as their major staple diet. In addition, the Areka Agricultural Research Center is located in this town which is working mainly in the root and tuber crops (enset, taro, sweet potato, cassava, and yam).

Sampling methods

Three sweet potato varieties (Koka-6, Falaha and Kulfo) with storage root flesh colors yellow, white and orange respectively were collected from Areka Agricultural Research Center (ArARC) as shown in Figure 3.1. All the samples were harvested within 5-6 months from planting, which is the maturation period of the selected sweet potato cultivars (Geleta, 2009). The sampling technique used was judgment sampling method; from the plant department experienced horticulturists who work in the research center helped me during selection of the sampling varieties. All fresh samples harvested from the ground were selected based on visual examination. All three sweet potato samples selected contain large, middle and small storage root sizes. In addition, all samples were not damaged during harvest and not attacked by pests. About four kgs of sweet potato storage root samples were collected from each variety. Samples were packed in polyethylene bags, kept in an ice box (to prevent moisture loss) and transported to Addis Ababa University of Food Science and Nutrition Program within ten hours.



A) Koka-6(Yellow)

B) Falaha (White)

C) Kulfo (Orange)

Figure 3.1: Three sweet potato varieties with different storage root flesh colors

3.3. Experimental study setting

The experiment was conducted on raw unpeeled and peeled yellow, white and orange fleshed sweet potato roots for analysis of nutritional composition and antinutritional factors and bread from composite flours of wheat-selected (orange fleshed) sweet potato blend was also analyzed for nutritional composition, antinutritional factors, quality and sensory attributes. Breads were baked in Entoto Technical and Vocational Education Training (TVET) at department of hotel management. A laboratory experiment was conducted at the laboratories of Food Science and Nutritional Program (AAU), Chemistry department (AAU) and Ethiopian Health and Nutrition Research Institute (EHNRI).

3.4. Preparation of sweet potato flour

Flour from sweet potato was prepared based on the method described by Adeleke and Odedeji (2010) and shown in figure 3.2. In the laboratory, within 24 hours of harvesting for all varieties root samples with all root sizes were carefully selected and mixed separately for purpose of including all size in the study. The selected samples were manually cleaned by hand followed with clean water to remove adhering materials and soils. Then the cleaned samples were divided in to two parts for further operation. One portion was hand peeled and submerged in water to avoid enzymatic browning and then sliced to uniform thickness using a stainless steel knife. The slices were blanched in hot water (80°C) for 5 minutes in order to inactivate enzymes that may cause browning reaction and followed by immediate cooling in cold water to avoid further cooking (Eluagu and Onimawo, 2010). The cooled slices were then drained on perforated plastic

tray. The slices were dried in a hot air oven (drying oven model, DHG-9055A) at 60⁰c until the chips were brittle and easy to be milled (overnight). The dried samples were milled into fine powder using electric grinder (High-Speed sampling machine model- FW100) until to pass through 0.425mm sieve mesh size and finally packed into airtight polyethylene plastic bags to minimize heat build-up and kept in the desiccators until needed for analysis. Sample preparation for second portion was the same as above except that the cleaned samples were unpeeled.

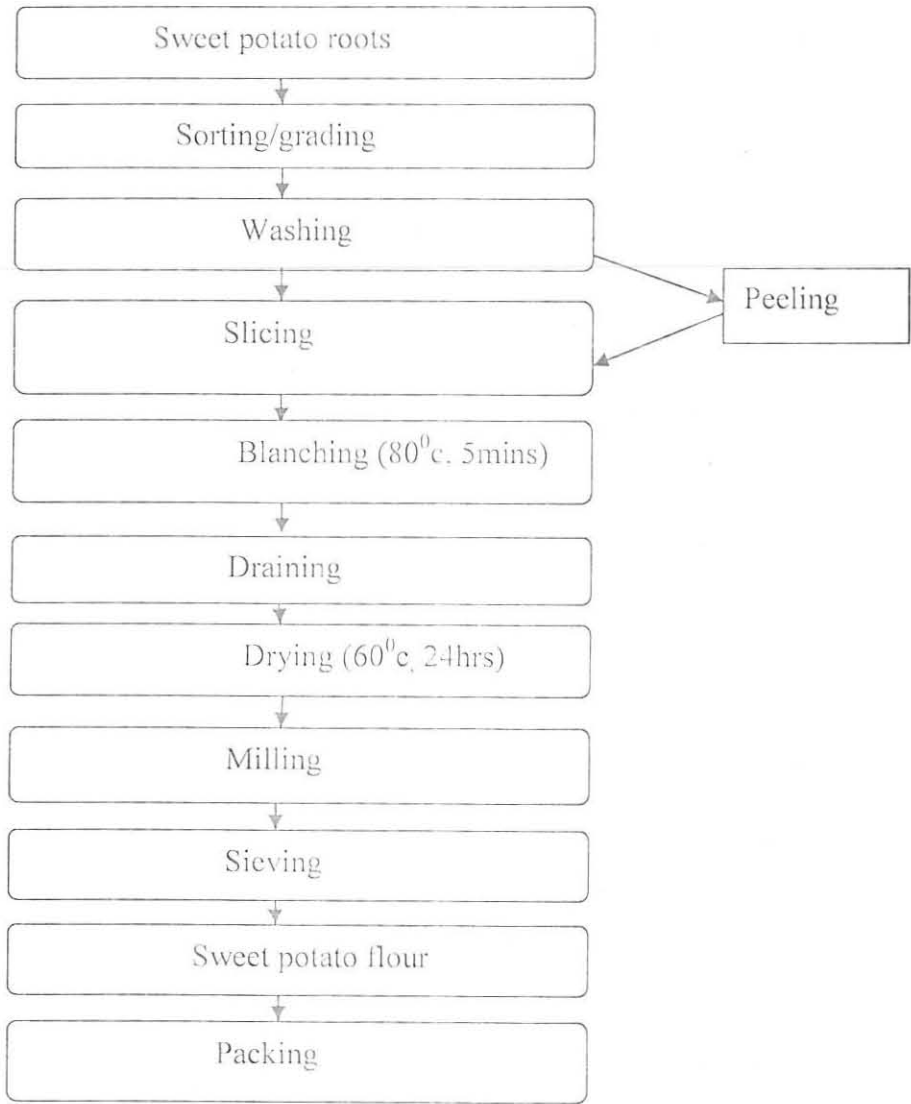


Figure 3.2: Flow chart for the preparation of orange sweet potato flour

3.5. Preparation of composite flour

Six different blend proportions including control were designed (Table 3.1) based on the blend proportions used by Ifie (2011) in his bread formulated from sweet potato flour and wheat flour with slight modifications such that 5% and 10% more sweet potato flours are included in this blend preparation. The appropriate amounts of sweet potato and wheat flours were weighed using an electronic balance to give the various ratios of the composite flour and then mixed with laboratory mixing machine to get the uniform dispersion and stored in air tight containers until use.

Table 3.1 Blending ratios of orange sweet potato flour and wheat flour in bread formulation

Sweet potato flour (%)	Wheat flour (%)
0	100
5	95
10	90
15	85
20	80
25	75

3.6. Bread preparation processes

Breads were formulated, prepared and baked based on the straight dough method used by Anton (2008) with slight modifications as the mixtures were mixed and kneaded with water in a flat wooden material manually instead of using electric mixer. Except water (variable) similar amount of all ingredients such as flour (100%), salt (1%), improver (1.5%) and yeast (2%) were used in each blend during the preparation of the dough (Table3.2). These ingredients in bread formulation were determined based on knowledge from traditional experienced bakers and literatures (Mepba, 2007; Mardiana, 2008; Jolaosho, 2010; Ukpabi, 2010).

Table 3.2 Ingredient used in dough formulation per loaf

Ingredient	Composition (%)
Flour	100
Yeast	2
Salt	1
Improver	1.5
Water	Variable

For bread baking, the straight dough method was used (Anton, 2008), all the ingredients were added at the same time (Figure 3.3) and mixed manually for 5 minutes and kneading was done until consistent dough was obtained. The resulted dough was left to rest for 20 min at room temperature (first proofing) then 100g piece of dough was divided, rolled and molded. Each piece was placed in metal pan and let to ferment for 45 minutes at room temperature (final proofing) then the baking process was carried out in electrically heated oven at 200⁰C for 20 min. After baking loaves were separated from the metal pan and allowed to cool at room temperature before evaluation. The cooled loaves were dried at 60⁰C for 9 hours and milled in to a fine powder using electric grinder (High-Speed sampling machine model- FW100) until to pass through 0.425mm sieve mesh size and finally packed into airtight polyethylene plastic bags, labeled and stored in dry place until used for analysis.

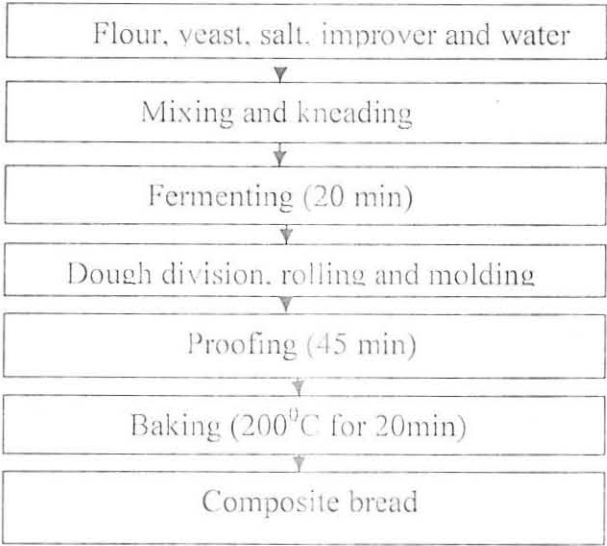


Figure 3.3: Flow chart for bread making process

3.7. Methods of Analysis

3.7.1. Determination of functional properties of composite flours

3.7.1.1. Water absorption capacity (WAC)

Water absorption capacity was determined using the centrifuge method of Sosulki (1962) as cited in Edema *et al.* (2005). Sample of 2.5g composite flour was mixed with 30ml distilled water in a 50ml centrifuge tube. The tube was agitated by vortex for about 5 min before being centrifuged at 4000rpm for 20 min. The mixture was decanted and the clear supernatant discarded. Adhering drops of water were carefully siphoned as much as quantitatively possible and the tube was reweighed. WAC was expressed as the weight of water bound by 100g dry flour.

3.7.1.2. Gluten content

The gluten amount was evaluated by the standard methods of AACC test procedure (AACC, 2000) which involves mixing followed by dough development and washing. Ten grams of flour samples were weighed and dough was prepared by mixing it with distilled water. After 30 minutes the developed dough was washed with 2% NaCl solution for 5 minutes (until all the starch and soluble protein were removed completely). The gluten after washing was rinsed with tap water to remove salt from it. Then the elastic material that remains behind the washing was taken as wet gluten. Gluten amount was calculated as the ratio of the weight of wet gluten to the weight of composite flour used.

3.7.2. Evaluation of bread quality parameters

Bread characteristics or baking qualities were evaluated by measuring the loaf volume, specific loaf volume and the organoleptic characteristics of final bread. The loaf volume was measured 50 minutes after loaves were removed from the oven by using seed displacement method (Mepba *et al.*, 2007) with slit modification using chickpea (*Cicer arietinum*) instead of barley seed. The loaf was put in a container with known volume (VC). The container was filled with chickpea, the loaf was removed and the volume of the chickpea was noted (VR). Loaf volume (VL) was then calculated according to the following formula: $\text{Loaf Volume}(\text{cm}^3) = \text{VC} - \text{VR}$

Loaf weight of bread (W)

Loaf weight (W) of bread was measured after cooling for one hour on digital balance (Masood *et al.*, 2011). Height of breads was measured using scale in centimeters.

Specific volume of loaf (VS)

Weight of loaf samples were taken and specific loaf volume was obtained by dividing the loaf volume by its corresponding loaf weight. Specific loaf volume (VS) was calculated in the following expression: **Specific Loaf Volume**(cm³/g) = $\frac{VL}{W}$

3.7.3. Sensory evaluation of bread

The sensory evaluation was carried out for consumer acceptance to evaluate loaf attributes such as appearance, aroma, taste, mouth feel and overall acceptability of the bread sample within two hours after baking. Twenty four panelists comprising of students and staff members from Food Science and Nutrition program of AAU and students and staff members of Hotel Management department in Entoto Technical and Vocational Education Training Institute (TVET) were randomly selected to perform the evaluation. Nine-point category scales was used to rate the attributes ranging from like extremely to dislike extremely as used by (Mepba *et al.*, 2007). Samples were evaluated on a desk placed an open well illuminated laboratory, which provided a quiet and comfortable environment.

In the sensory evaluation session, the bread samples were sliced into pieces of uniform thickness using knife and coded with arbitrary three digit numbers. The panelists were seated individually in order to avoid dependency of one panel on the other. The coded samples were presented in random to each panelist on identical white plastic tray at ambient temperature. Unsliced loaf was also provided along with sliced in order to evaluate general appearance of the bread sample. Panelists were asked to indicate their degree of liking for each attributes of the coded samples by choosing the appropriate category. Panelists were provided with palatable water to rinse their mouth before and after evaluating each sample in order to eliminate bias between evaluations.

3.7.4. Proximate analysis

3.7.4.1. Determination of moisture content

The moisture content was determined according to AOAC (2000) using the official method 925.09 by oven drying. A clean empty aluminum dishes and its lids were dried in drying oven (Model DHG- 9055A) at 105⁰C for 1 hour and cooled in desiccators with fresh granular silica gel desiccants for about 30 minutes and weighed. Each sample was mixed thoroughly and 5g of samples were weighed and transferred to the dish. The dishes and samples were placed in the drying oven and dried for four hours at 105⁰C. Then the samples were cooled in desiccators for 30 minutes and reweighed. Moisture content was calculated using the following formula:

$$\text{Moisture content (\%)} = \frac{\text{Weight of fresh sample} - \text{Weight of dry sample}}{\text{Weight of fresh sample}} \times 100$$

3.7.4.2. Determination of crude fiber content

Crude fiber content was determined according to AOAC (2000) using official method 962.09. About 1.5g weighed sample was placed into a 600ml beaker and about 200ml of 1.25% H₂SO₄ was added and boiled for 30 minutes. Recording was taken place by placing a watch glass over the mouth of the beaker. After 30 minutes heating by gently keeping the level constant with distilled water, 20ml of 28% KOH was added and again boiled gently for a further 30 minutes. Subsequently washing was conducted with 1% sulfuric acid and NaOH solution and filtering was followed. After filtering the sample was dried in an electric oven at 130⁰C for 2 hours and cooled for 30 minutes in the desiccators and weighed. Then it was ashed in a muffle furnace ashing for 30 minutes at 550⁰C and cooled in the desiccators and then re-weighed. Finally, the crude fiber content was calculated by using the following formula:

$$\text{Crude fiber(\%)} = \frac{W_1 - W_2}{W_3} \times 100$$

Where: W₁=weight of crucible and sample after drying

W₂=weight of crucible and sample after ashing, W₃=weight of sample

3.7.4.3. Determination of crude protein

Protein content was determined according to AOAC (2000) using the official method 979.09. About 0.5g samples were taken in a digestion flask and 6ml of concentrated sulfuric acid was added and left overnight. Then 3.5ml of 30% hydrogen peroxide and 3g of the catalyst mixture (75g of copper sulfate and 0.7g of potassium sulfate) were added in to digestion flask. The mixture was then exposed to a temperature of about 370⁰c for four hours in order to allow digestion. Then distillation was took place by adding 25ml of 40% sodium hydroxide to the digestion flask and using 25ml of 4% boric acid solution and three drops of methyl red solution as indicator into a 250ml conical flask. The distillation was continued until a total volume of 150-200ml is collected in conical flask. Finally, the distillated solution was titrated with standardized 0.1N hydrochloric acid to a pink color and the amount of hydrochloric acid was recorded. The crude protein content was estimated using the formula:

$$\text{Total nitrogen content (\%)} = \frac{(A-B) \times N \times 14.007}{W} \times 100$$

Where: A= volume (ml) of hydrochloric acid used in titration for the test sample

B = volume (ml) of hydrochloric acid used in titration of the blank

N = normality of hydrochloric acid used (0.1N)

14.007= Equivalent weight of nitrogen

W= weight in gram of a test sample

The protein content was calculated from the following equation:

Crude protein (%) = %Total nitrogen × 6.25 (for sweet potatoes)

Crude protein (%) = %Total nitrogen × 5.7 (for breads)

3.7.4.4. Determination of total ash content

Total ash content was determined according to AOAC (2000) using the official method 923.03. The porcelain dish used for the analysis was cleaned by drying oven at 105⁰C for 30 minutes and cooled in desiccators for 30 minutes was measured using analytical balance (M₁). About 2.5g of the sample was weighed in to porcelain dish (M₂). The dishes and their content were placed on a hot plate under a fume hood and the temperature was slowly increased until smoking ceases and the samples become thoroughly charred. The charred samples were placed inside the muffle furnace (Carbolite CSF 1200) at about 550⁰C for six hours until free from carbon and the residues

appear whitish color. The sample was then removed from the furnace and if the ashing was incomplete (traces of carbon are still evident) it was moistened by the few drops of de-ionized water and conc. HNO_3 added, dried and return to the furnace and re-ash at 550°C until white ash color was obtained. It was removed from the furnace and cooled in the desiccators and finally the mass was weighed (M_3). The amount of total ash was calculated by using the following formula:

$$\text{Total Ash}(\%) = \frac{W_3 - W_1}{W_2 - W_1} \times 100$$

Where: M_1 =Weight of the dish

M_2 = Weight of fresh sample and dish

M_3 = Weight of ash and dish

3.7.4.5. Determination of crude fat content

The crude fat content was determined according to AOAC (2000) using official method 4.5.01. The cleaned extraction flasks were dried by drying oven at 105°C for 30 minutes and then cooled for 30 minutes in desiccators and weighed. A clean, dried extraction thimble containing about 2g of dried sample and covered with fat free cotton at the bottom and top was placed into Soxhlet (SHANGHAI QIANJIAN INSTRUMENT CO., LTD) extraction chamber. Cooling water was switched on and a 50ml of Diethyl Ether was added to the extraction flask through the condenser. The extraction was conducted for about four hours. Finally, extraction flasks were dried in oven at 105°C for 30 minutes and cooled in the desiccators for 30 minutes and weighed. The crude fat content was determined as follows:

$$\text{Crude fat}(\%) = \frac{W_2 - W_1}{W} \times 100$$

Where: W_2 = Weight in gram of extraction flask and dried crude fat

W_1 =Weight in gram of extraction flask

W =Weight in gram of test sample

3.7.4.6. Determination of total carbohydrate

Total carbohydrate content was calculated by difference using the formula as follows:

$$\text{Carbohydrate (\%)} = 100 - (\% \text{ crude protein} + \% \text{ crude fiber} + \% \text{ total ash} + \% \text{ crude fat})$$

3.7.4.7. Determination of total energy

Total energy content was obtained using Atwater conversion factors 4, 9 and 4 for each gram of crude protein, crude fat and carbohydrate and expressed in calories, respectively (Guyot *et al.*, 2007).

$$\text{Total energy} \left(\frac{\text{Kcal}}{100\text{g}} \right) = (9 \times \% \text{Fat}) + (4 \times \% \text{Protein}) + (4 \times \% \text{Carbohydrate})$$

3.8. Mineral Analysis

3.8.1. Analysis of Calcium, Iron, Magnesium and Zinc

Calcium, magnesium, iron and zinc were determined according to the standard method of AOAC (2000) using an Atomic Absorption Spectrophotometer (Varian SAA-20 Plus). Ashing of the samples were followed by digestion and absorption.

Ashing: carefully washed silica dishes were dried in oven at 105°C for 15 minutes and cooled in desiccators about 30 minutes at room temperature and weighed. About 2.50g of sample was transferred into each dish and placed on a hot plate under a fume-hood in slowly increasing temperature until smoking ceases. The charred sample was placed in a muffle furnace at about 550°C until free from carbon and the residues appear white in color. The samples were then removed from the muffle furnace and if the ashing was incomplete it was further moistened by a few drops of de-ionized water and concentrated nitric acid and dried on a hot plate and re-ashed in the furnace at 550°C until white ash color was obtained.

Digestion: the ash was digested with 5ml of 6N HCl to wet it completely and carefully dried on a low temperature hot plate. Seven ml of 3N HCl was added on each dish and heated on a hot plate until the solution just boils. Then the solution was cooled to room temperature and filtered through a filter paper (Whatman) into 50ml volumetric flask retaining as much of the solids as possible in the dish. Again 5ml 3N HCl was added to the dish to dissolve the residue and it was

heated until the solution just boiled. Then the solution was cooled and filtered in to the same 50ml volumetric flask. The dish was then washed with water and filtered in to the volumetric flask. Since calcium is to be determined 2.5ml of 10% Lanthanum chloride solution was added in 50ml volumetric flask that contained the filtrate. Finally, the flask was filled with freshly de-ionized water up to the mark. Blank was also prepared in parallel with the sample using the same amount of reagents that were used for the sample through all steps.

Standard solutions: Five series of working standard solutions for Ca, Mg, Fe and Zn were prepared from 1000ppm metals stock solutions with de-ionized water containing 2.4ml 3N HCl and 0.5ml Lanthanum chloride in 10ml volumetric flask used to make the sample and standard matrix similar. The stock standard solutions of minerals (zinc, calcium, iron and magnesium) were diluted with 0.3N HCl to concentrations that fall within the working range (0.5, 1.5, 2.0, 2.5 and 3.0 (µg/ml) for calcium analysis; 2, 6, 10 and 12 (µg/ml) for iron analysis; 0.5, 1.0, 1.5 and 2.0 (µg/ml) for zinc analysis; 0.25, 0.50, 1.0 and 2.0 (µg/ml) for magnesium analysis).

The apparatus were set according to the instructions and a calibration curve was prepared by plotting the absorption values against the metal concentration in (µg/ml). The Fe, Zn, Ca and Mg content in the sample was determined using Atomic Absorption Spectrophotometer at 248.3nm, 213.9nm, 422.7nm and 285.2nm wavelengths, respectively. Three reading were taken from the graph for each metal which depicted the metal concentrations that correspond to the absorption values of the samples and the blank. The metal contents were calculated by using the following formula:

$$\text{Metal content} \left(\frac{\text{mg}}{100\text{g}} \right) = \frac{(A - B) \times V}{10 \times W}$$

Where: W=Weight of the sample in gram

A=Concentration (µg/ml) of sample solution

B=Concentration (µg/ml) of blank solution

V = Volume of the extract (50ml)

3.8.2. Phosphorus determination

The sample solutions prepared for mineral determination was used for phosphorous determination. About 1ml of the clear extract was diluted into 50ml with de-ionized water in a 100ml volumetric flask. Five ml of the sample dilution was added into test tubes. A 0.5ml of molybdate and a 0.2ml aminonaphtholsulphonic acid were added into the test tubes (sample solution) and mixed thoroughly step by step. Again 0.2ml aminonaphtholsulphonic acid was added into the test tubes repeatedly until the solution becomes clear and then the solution was allowed to stand for 10 minutes. Standard and blank solutions were prepared as above but 5ml of working standard and 5ml of de-ionized water in place of the sample dilution were used, respectively.

Six series of working standard phosphorus solutions (0, 0.2, 0.4, 0.6, 0.8 and 1.0 μ g/ml) were prepared by dissolving 438.8mg of KH_2PO_4 in some water in a 100ml volumetric flask and added 1ml of concentrated H_2SO_4 and dilute to the mark with de-ionized water. After setting the instrument operation process, the absorbance (A) of the sample solution was measured at 660nm against distilled water using UV-VIS spectrometer. The standard and sample blank solution analysis was carried out simultaneously with sample solution. Calibration curve (concentration versus absorbance) prepared and used to measure the amount of phosphorus in the test sample as follows:

$$\text{Phosphorus} \left(\frac{\text{mg}}{100\text{g}} \right) = \frac{(A - B) \times \text{dilution factor} \times \text{extracted volume}}{\text{Slope} \times \text{Weight of sample} \times 1000} \times 100$$

Where: A= absorbance of sample, B=absorbance of blank, Slope= obtained from the calibration

3.9. Analysis of antinutritional factors

3.9.1. Determination of phytate

Phytate content was determined using method described by Latta and Eskin (1980) and later modified by Vaintraub and Lapteva (1988). About 0.5g of dried sample was extracted with 10ml 0.2N HCl in a mechanical shaker for one hour at an ambient temperature and centrifuged at 3000rpm for 30 minutes. About 3ml of the clear supernatant (sample solution) was transferred into test tube for phytate estimation. About 2ml of waste reagent (0.03% solution of $\text{FeCl}_3 \cdot 6\text{H}_2\text{O}$

and 0.3% of sulfosalicylic acid in water) was added to sample solution and mixed with a vortex (Thermolyne mixer) for 5 seconds and centrifuged. Standard blank solution was prepared as above but 3ml of standard in place of the sample dilution was used.

Six series of working standard phytic acid solutions (0, 4.5, 9.0, 18, 27 and 36µg/ml) were prepared by dissolving 0.1814g of phytic acid in 100ml of 0.2N HCl. After setting the instrument operation process, the absorbance (A) of the sample solution was measured at 500nm against de ionized water using UV-VIS spectrometer (Model CECIC, CE1021). The standard and sample blank solution analysis was carried out simultaneously with sample solution. Calibration curve (concentration versus absorbance) prepared and used to measure the amount of phytic acid in the test sample as follows:

$$\text{Phytic acid} \left(\frac{\text{mg}}{100\text{g}} \right) = \frac{[(A - B) - \text{Intercept}]}{(\text{Slope} \times \text{Weight of sample})} \times \{10/3\}$$

Where: A= absorbance of sample

B = absorbance of blank

Slope and Intercept = obtained from the calibration curve

Phytate mineral molar ratio calculation:

Phytate calcium molar ratio was obtained (mg of phytate/molecular weight of phytate divided by mg of calcium/molecular weight of calcium).

Phytate iron molar ratio was obtained (mg of phytate/molecular weight of phytate: mg of iron/molecular weight of iron).

Phytate zinc molar ratio was obtained (mg of phytate/molecular weight of phytate: mg of zinc /molecular weight of zinc).

Phytate x calcium/zinc millimolar ratio was obtained (mg of phytate/molecular weight of phytate) (mg of calcium/molecular weight of calcium)/ (mg of zinc/molecular weight of zinc) divided by 100.

3.9.2. Determination of condensed tannin

Tannin content was determined using the method of Burns (1971) as modified by Maxson and Rooney (1972). About 1g weighed sample was transferred into a screw cap test tube and 10ml of 1% HCl in methanol was added to extract and then the test tube was placed on mechanical

shaker for 24 hours at room temperature. Then the sample solution was centrifuged (Adam smith) at 1000rpm for five minutes. About 1ml of supernatant was taken from sample solution and mixed (Vortex mixer) with 5ml of vanillin-HCl reagent (mixture of 4% vanillin in methanol and 8%HCl in methanol) in another test tube and then the mixture was left for 20 minutes to complete the reaction. Standard and blank solutions were prepared as above but (0.2-1.0) ml of stock solution and empty test tube were used in place of the sample solution, respectively.

Preparation of the standard curve: D-catechin was used as standard value for condensed tannin determination (tannin in mg D-Catechin/g of sample). Six series of stock solutions (0, 0.2, 0.4, 0.6, 0.8 and 1.µg/ml) were prepared by dissolving 40mg of D- catechin in 1000ml of 1% HCl in methanol. Then the volume of each test tube was adjusted to 1ml with 1% HCl in methanol and 5ml of vanillin-HCl reagent was added into each test tube and the test tube was kept for 20 minutes to complete the reaction. Finally, the absorbance of sample solutions and the standard solution were measured at 500nm using UV-VIS spectrophotometer (model CE1021) and the standard curve was made from absorbance versus concentration. The slope and intercept were used for calculation. The condensed tannin content in the sample was calculated using formula:

$$\text{Condensed tannin} \left(\frac{\text{mg}}{100\text{g}} \right) = \frac{(A - B) - \text{Intercept}}{\text{Slope} \times d \times W}$$

Where: A = Sample absorbance, d = Density of solution (0.791g/ml)

B = Blank absorbance, W = Weight of sample in gram

3.9.3. Determination of oxalate

Oxalate content of sample was determined using method originally employed by Ukpabi and Ejidoh (1989) which involves digestion, precipitation and titration.

Digestion: Two gram weighed sample was suspended in 190ml de-ionized water contained in a 250ml conical flask. The sample solution was digested by adding 10ml of 6M HCl at 100⁰c for one hour. The digested solution was cooled and made it up to 250ml using distilled water and then filtered.

Oxalate precipitation: duplicate portion of 125ml of filtrate were measured in to a beaker and four drops of methyl red indicator added, followed by the addition of concentrated NH₄OH

solution drop wise until the test solution changes from salmon pink color to faint yellow color (pH 4-4.5). Each portion was then heated to 90⁰c, cooled and filtered to remove precipitate containing ferrous ion. The filtrate was then again heated to 90⁰c and 10ml of 5% CaCl₂ solution was then added while being stirred constantly. After heating it was cooled and left overnight in refrigerator (5⁰c). The solution was then centrifuged at a speed of 2500rpm for 5 minutes. Then the supernatant was decanted and the precipitate completely dissolved in 10ml of 20% (v/v) H₂SO₄ solution.

Permanganate titration: at this point the total filtrate resulting from digestion of 2g test sample was made up to 300ml using distilled water. Aliquots of 125ml of filtrate were heated until near boiling and then titrated against 0.05M standard KMnO₄ solution to a faint pink color which persists for 30 seconds.

$$Oxalate(\frac{mg}{100g}) = \frac{T \times V_{me} \times D_f \times 10^5}{ME \times W}$$

Where: T = the titre of KMnO₄ (ml)

V_{me} = the volume-mass equivalent (i.e. 1 cm³ of 0.05 MKMnO₄ solution is equivalent to 0.00225g anhydrous oxalic acid)

D_f = the dilution factor VTA (2.4, where VT is the total volume of filtrate (300ml) A is the aliquot used (125 ml))

ME = the molar equivalent of KMnO₄ in oxalate (KMnO₄ redox rxn+ 5)

W = the mass of flour used

3.10. Statistical analysis

Data for nutritional and antinutritional factors of yellow, white and orange sweet potato cultivars in their roots unpeeled and peeled conditions were analyzed with two-way ANOVA to evaluate the effects of variety and processing. The effect of blending ratio on nutritional, antinutritional and sensory attributes of breads was analyzed with one way ANOVA. Mean differences were statically significant at p<0.05 and the means of each parameter were compared using Duncan's multiple range test procedures to separate the means using SPSS, version 15.0 software. Results were reported ± standard error (SE) of duplicate and triplicate.

4. Results and Discussions

4.1. Proximate composition of yellow, white and orange fleshed sweet potatoes

The mean values for proximate compositions such as moisture, crude protein, crude fat, total ash, crude fiber, total carbohydrate and total energy of three sweet potato cultivars of raw roots in their unpeeled and peeled states were investigated and the effects of results are presented in Table 4.1.

Table 4.1 Proximate composition (g/100g) of yellow, white and orange fleshed sweet potatoes

Variety	Moisture*	Protein	Fat	Fiber	Ash	CHO**	Energy***
UYSP ^b	71.73 ± 0.05 ^d	6.50 ± 0.05 ^a	0.49 ± 0.02 ^d	6.65 ± 0.00 ^a	3.49 ± 0.09 ^d	82.88±0.16 ^c	361.86±0.30 ^d
UWSP	72.45 ± 0.03 ^c	4.60 ± 0.10 ^b	0.53 ± 0.03 ^d	5.24±0.01 ^b	4.84 ± 0.05 ^a	84.79±0.22 ^d	368.12±0.20 ^c
UOSP	76.97 ± 0.23 ^a	2.84 ± 0.41 ^{cd}	1.00 ± 0.07 ^b	4.52±0.01 ^c	4.94 ± 0.04 ^a	86.72±0.30 ^c	373.97±1.87 ^b
PYSP	68.58 ± 0.45 ^f	4.41± 0.07 ^b	0.66 ± 0.00 ^c	3.59 ± 0.08 ^c	3.04 ± 0.04 ^c	88.32±0.04 ^{ab}	376.90±0.20 ^a
PWSP	70.51 ± 0.60 ^e	3.46 ± 0.01 ^c	0.72 ± 0.01 ^c	2.94±0.09 ^f	4.04 ± 0.05 ^c	88.86±0.14 ^a	375.65±0.45 ^{ab}
POSP	74.84 ± 0.13 ^b	2.48 ± 0.24 ^d	1.12 ± 0.01 ^a	3.83±0.06 ^d	4.33 ± 0.03 ^b	88.01±0.04 ^b	373.05±0.25 ^b

Reported values are the mean ±SE (n=2). Means with different letters in the same column are significantly different (P<0.05). NB: UYSP & PYSP (Unpeeled and peeled Yellow Sweet Potato), UWSP & PWSP (Unpeeled and peeled White Sweet Potato) and UOSP & POSP (Unpeeled and peeled Orange Sweet Potato), respectively. *Wet basis, **Total Carbohydrate, *** in Kcal/100g.

4.1.1. Moisture content

The moisture content of three sweet potato varieties was significantly affected (P<0.05) by processing and variety but their interaction did have a non significant effect. The mean values for moisture content among three sweet potato cultivars with two processing methods (Table 4.1) showed statistically significant variations; ranged from 71.73-76.97 and 68.58-74.84g/100g for unpeeled and peeled conditions, respectively. It was observed that the mean moisture content of yellow, white and orange sweet potato varieties were 71.73, 72.45 and 76.97g/100g and 68.58, 70.51 and 74.84 g/100g for unpeeled and peeled cases, respectively. According to the result of statistical analysis, the mean moisture content of orange sweet potato variety was significantly (P<0.05) higher than that of both yellow and white sweet potato varieties in both unpeeled and peeled conditions. Similarly, mean moisture content of white sweet potato variety was

significantly ($P<0.05$) higher compared to the mean moisture content of yellow sweet potato variety in both unpeeled and peeled conditions.

On the other hand, peeling was significantly decreased ($P<0.05$) the mean moisture content of all three sweet potato varieties. This may be higher amount of water is contained in outer skin layer than that of inner flesh layer of sweet potato roots. Results considering moisture in the present study are in the same line with works of (ENV/JM/MONO, 2010) that had been reported the average moisture content of (77.3g/100g) and (66.1-74.9)g/100g raw sweet potato root samples with skin and without skin, respectively. Moreover, the mean range values of moisture content in the current study are also comparable to the average moisture content that had been reported by Purcell *et al.* (1989) for 16 sweet potato varieties grown in North Carolina (71.7-76.3%), 13 sweet potato varieties grown in West New Guinea (69.21-77.2%) and 6 sweet potato varieties grown in Ugandan (60.8-69.7%). The reason for the observed differences in moisture content of samples in the present study from earlier works could be attributed to the variety difference, the climate, the type of soils and others factors while the observed differences in moisture content in the current study might be contributed by variety difference.

4. 1.2. Crude protein content

The crude protein content of three sweet potato varieties was significantly affected ($P<0.05$) by processing, variety and their interaction. As indicated in (Table 4.1), significant differences ($p<0.05$) exist between the protein content of the three sweet potato cultivars and the value ranged from 2.84-6.50g/100g in unpeeled and 2.48-4.41g/100g in peeled conditions. The mean crude protein value of yellow, white and orange sweet potato varieties was 6.50, 4.60 and 2.84g/100g and 4.41, 3.46 and 2.48g/100g for unpeeled and peeled roots, respectively. The crude protein content of yellow sweet potato variety was significantly ($P<0.05$) higher than that of white and orange sweet potato varieties in both unpeeled and peeled conditions. Similarly, the mean crude protein content of white sweet potato variety was significantly ($P<0.05$) higher compared to the mean crude protein content of orange sweet potato variety in both unpeeled and peeled cases. Such observed differences in crude protein content in the current study might be contributed by cultivars or genetic difference, since all the studied varieties were collected from the same environment and soil type. These results are well agreed within the range of values (1.73 to 11.8%) that had been reported by Purcell *et al.* (1989). It was observed that peeling

decreases the mean crude protein contents of the three sweet potato varieties; this may be higher amount of protein is accumulated in outer skin layer than that of inner flesh layer of sweet potato roots. Similar results had been reported by (William *et al.*, 1984; ENV/JM/MONO, 2010).

4.1.3. Crude fat content

It was observed that the crude fat content is generally low in all investigated sweet potato cultivars; a similar idea had been reported by Boggess *et al.* (1971). The crude fat content of the three sweet potato varieties was indicated to be significantly affected ($P<0.05$) by processing and variety but not in their interaction. Result in Table 4.1 shows that the mean fat content of three sweet potato cultivars was significantly varied and the mean value ranged from 0.49-1.00g/100g in unpeeled and 0.66-1.12g/100g peeled conditions. The observed value of crude fat in yellow, white and orange sweet potato varieties were 0.49, 0.53 and 1.00g/100g and 0.66, 0.72 and 1.12g/100g in unpeeled and peeled roots, respectively. The mean crude fat content of orange sweet potato variety was significantly ($P<0.05$) higher than that of both yellow and white sweet potato varieties in their unpeeled and peeled cases. Yellow sweet potato cultivar contain lower level of mean crude fat content than that of white sweet potato cultivar in both unpeeled and peeled states but the value was not significantly different ($P>0.05$). This observed difference among the three sweet potato cultivars may be contributed by genetic variation, since other factors are kept constant.

On the other hand, the mean crude fat content was observed to be significantly higher ($P<0.05$) in peeled than that of unpeeled sweet potato root in all their corresponding varieties. This might be dietary fat more accumulated in inner flesh layer than that of outer skin layer of sweet potato roots though biological processes. This result was similar with reported value of ENV/JM/MONO (2010) that the level of average fat content in peeled sweet potato roots (0.6-0.7%) is higher than that of unpeeled roots (0.2%).

4.1.4. Crude fiber content

Foods with high fiber can reduce caloric uptake and provide health benefits concerned to reduce incidences of chronic diseases such as colon cancer, diabetes, heart diseases and certain digestive diseases (Wanda and Walter, 1989). The crude fiber content of three sweet potato varieties was significantly affected ($P<0.05$) by processing, variety and their interaction. It was observed that

the mean crude fiber content of three sweet potato cultivars was significantly varied (Table 4.1) and the mean value ranged from 4.52-6.65g/100g for unpeeled and 2.94-3.83 g/100g for peeled roots. The mean fiber content of yellow, white and orange sweet potato varieties was 6.65, 5.24 and 4.52g/100g and 3.59, 2.94 and 3.83g/100g for unpeeled and peeled roots, respectively. The mean crude fiber content of yellow sweet potato variety was significantly ($P<0.05$) higher than that of both white and orange sweet potato varieties in unpeeled condition but the value was significantly ($P<0.05$) higher in orange sweet potato variety than that of both white and yellow sweet potato varieties in peeled condition. The result also indicated that the mean crude fiber content of white sweet potato variety was significantly ($P <0.05$) higher compared to the mean value of orange sweet potato variety for unpeeled and was significantly ($P <0.05$) lower for peeled case.

On the other hand, processing conditions were indicated that the mean crude fiber value was significantly higher ($P<0.05$) in unpeeled sweet potato root than that of peeled sweet potato root in all their corresponding varieties. This might be more dietary fiber accumulated in outer skin layer than that of inner flesh layer of sweet potato root. A similar finding had been reported by ENV/JM/MONO (2010) that the level of average fiber content in unpeeled raw sweet potato root (13.2 g/100g) is higher than that of peeled one (6.8g/100g).

4.1.5. Total ash content

Ash content in a food item shows inorganic residues after the organic substance has been burnt away and it gives clue of the total mineral content of a food product (Olaoye *et al.*, 2007). The ash content of three sweet potato varieties was significantly affected ($P<0.05$) by processing, variety and their interaction. The studied three sweet potato cultivars were significantly varied (Table 4.1) in their total ash content and the mean value ranged from 3.49-4.94g/100g in unpeeled and 3.04-4.33g/100g in peeled cases. The mean ash value of yellow, white and orange sweet potato varieties was 3.49, 4.84 and 4.94g/100g and 3.04, 4.04 and 4.33g/100g for unpeeled and peeled roots, respectively. The mean total ash content of yellow sweet potato variety was significantly ($P<0.05$) lower than that of both white and orange sweet potato varieties in both unpeeled and peeled roots. Orange sweet potato cultivar has the highest mean ash content than that of white and yellow sweet potato cultivars in both unpeeled and peeled conditions but

significant difference was not observed in unpeeled root of orange and white sweet potato cultivars.

In considering effect of processing, similar trend was observed like in fiber; the mean ash content was significantly higher ($P<0.05$) in unpeeled sweet potato root than that of peeled sweet potato root in all their corresponding varieties. This might be either more inorganic matter is accumulated in outer skin layer than that of inner flesh layer in storage sweet potato root or some inorganic matter that adhered the skin layer of root might be contributed during processing. A similar trend was observed in ENV/JM/MONO (2010) that unpeeled (4.4g/100g) raw sweet potato roots contain high average ash content than that of peeled (2.6-4.0g/100g) one.

4.1.6. Total carbohydrate content

The total carbohydrate content was determined by difference. The total carbohydrate content of three sweet potato varieties was significantly affected ($P<0.05$) by processing, variety and their interaction. All the investigated sweet potato cultivars were significantly varied (Table 4.1.) in their carbohydrate content and the mean value ranged from 82.88-86.72g/100g in unpeeled and 88.01-88.86g/100g in peeled conditions. The mean carbohydrate content of yellow, white and orange sweet potato varieties was 82.88, 84.79 and 86.72g/100g and 88.32, 88.86 and 88.01g/100g for unpeeled and peeled roots, respectively. The mean carbohydrate content of orange sweet potato variety was significantly ($P<0.05$) higher than that of both yellow and white sweet potato varieties in case of unpeeled root samples while white sweet potato variety has the highest carbohydrate content in peeled condition.

Generally, the carbohydrate contents in all investigated sweet potato cultivars were high. A similar idea had been reported by Collins and Walter (1982) that most of the dry matter (85 to 90%) of the sweet potato was carbohydrate. Effect of processing also showed that peeling was significantly increased ($P<0.05$) the mean carbohydrate content of three sweet potato varieties. These observed variations might be result from the difference in the protein, fat, ash and fiber content of varieties and processing.

4.1.7. Total energy content

The energy content of three sweet potato varieties was found significantly influenced ($P<0.05$) by processing, variety and their interaction. All the investigated sweet potato cultivars were significantly varied (Table 4.1) in their energy content and the mean value ranged from 361.86-373.97Kcal/100g in unpeeled and 373.05-376.90Kcal/100g in peeled root samples. The observed mean energy value of yellow, white and orange sweet potato varieties was 361.86, 368.12 and 373.97g/100g and 376.90, 375.65 and 373.05g/100g for unpeeled and peeled roots, respectively. The mean energy content of orange sweet potato variety was significantly ($P<0.05$) higher than that of both yellow and white sweet potato varieties in unpeeled root samples while the lowest value was obtained in yellow sweet potato in the same condition. In peeled condition, the highest and lowest mean energy content was observed in yellow and orange sweet potato varieties, respectively even though significant difference was not observed between yellow and white and orange and white sweet potato cultivars.

Similarly carbohydrate, the energy contents in all investigated sweet potato cultivars were high. Thus, the principal use of sweet potato like other starchy root and tuber crops as human food and animal feed is therefore as a source of dietary energy yielding ingredients (Philip, 1991). Effect of processing also revealed that peeling was significantly increased ($P<0.05$) the mean energy content of all the studied sweet potato cultivars. The observed variations in energy content in variety and processing may be contributed from the difference in the protein, fat and fiber content of varieties and processes.

4.2. Mineral composition of yellow, white and orange fleshed sweet potatoes

In this section three sweet potato varieties for mineral (calcium, magnesium, phosphorus, iron and zinc) content in their raw roots unpeeled and peeled conditions were analyzed and the average results are presented in Table 4.2.

4.2.1. Calcium content

The calcium content of three sweet potato varieties was significantly affected ($P<0.05$) by processing, variety and their interaction. All the investigated sweet potato cultivars were significantly varied (Table 4.2) in their calcium content and the mean value ranged from 7.42-

47.04mg/100g and 5.28-45.54mg/100g in unpeeled and peeled root samples, respectively. The mean calcium content of yellow, white and orange sweet potato varieties were 7.42, 7.95 and 47.04mg/100g and 5.28, 6.04 and 45.54mg/100g for unpeeled and peeled roots, respectively. The mean calcium content of orange sweet potato variety was significantly ($P<0.05$) higher than that of both yellow and white sweet potato varieties in both unpeeled and peeled conditions while yellow sweet potato variety contains the lowest in both unpeeled and peeled cases. This variation might be contributed by cultivar difference. A similar idea had been reported by Elkins (1979) and Lopez *et al.* (1980) that the level of calcium content is varied from cultivar to cultivar and the observed average value was 17.4-32.7 (mg/100g). In some sweet potato cultivars, high level of average calcium (78.6mg/100g) content had been reported by (Purcell *et al.*, 1989). The observed variation between average range value of calcium content in this result and earlier finding might be attributed by cultivars, climate, soil types, location and other factors (Serge, 1996).

On the other hand, effect of processing revealed that peeling was significantly decreased ($P<0.05$) the mean calcium content of all studied sweet potato varieties. This result is expected because higher value of average ash content was observed in the outer skin layer of sweet potato root than that of inner flesh layer during proximate study currently; hence ash is indicative of the amount of minerals contained in any food sample (Olaoye *et al.*, 2007). Moreover, there might be either more inorganic matter is accumulated in outer skin layer than that of inner flesh layer in storage sweet potato root or some minerals that are adhered with the outer layer of the root from the soil may be attributed calcium during processing. A similar finding had been reported by ENV/JM/MONO (2010).

4.2.2. Iron content

The iron content of three sweet potato varieties was significantly affected ($P<0.05$) by processing, variety and their interaction. The mean values for iron content among three sweet potato cultivars with different processing methods (Table 4.2) showed statistically significant variations; ranged from 11.51-15.26mg/100g in unpeeled and 8.70-11.45mg/100g in peeled root samples. The mean iron value of yellow, white and orange sweet potato varieties was 11.51, 13.35 and 15.26mg/100g and 8.70, 9.69 and 11.45mg/100g for unpeeled and peeled conditions, respectively. The mean iron content of orange sweet potato variety was significantly ($P<0.05$)

higher than that of both yellow and white sweet potato varieties in unpeeled and peeled root samples. Similarly as calcium, yellow sweet potato variety contains the lowest iron content in both unpeeled and peeled cases. A similar finding had been reported by Elkins (1979) and Lopez *et al.* (1980) that the level of iron content is varied from cultivar to cultivar and the observed average value was 0.85-9.59 (mg/100g). In some sweet potato varieties, low level of iron (1.72mg/100g) content had been reported by (Purcell *et al.*, 1989). This variation might be for the same reasons of calcium content that was mentioned above. The unpeeled root samples contain high level of iron content than that of peeled root samples in all investigated sweet potato cultivars; this might be for similar reasons that are mentioned in calcium content.

Table 4.2 Mineral composition (mg/100g) of yellow, white and orange sweet potatoes

Variety	Calcium	Phosphorus	Iron	Zinc	Magnesium
UYSP	7.42±0.01 ^d	19.22±0.01 ^c	11.51±0.02 ^c	1.14±0.01 ^c	5.86±0.11 ^a
UWSP	7.95±0.02 ^c	24.50±0.01 ^a	13.35±0.01 ^b	1.97±0.01 ^a	5.98±0.025 ^a
UOSP	47.04±0.05 ⁱⁱ	22.11±0.01 ^b	15.26±0.02 ^a	1.30±0.01 ^b	3.00±0.075 ^b
PYSP	5.28 ± 0.01 ^f	15.70± 0.10 ^f	8.70 ± 0.01 ^f	0.68± 0.01 ^f	UD
PWSP	6.04± 0.01 ^c	21.80 ± 0.01 ^c	9.69 ± 0.01 ^c	0.79±0.01 ^c	UD
POSP	45.54 ± 0.01 ^b	20.67 ± 0.01 ^d	11.45 ± 0.01 ^d	0.93±0.02 ^d	UD

Reported values are the mean ±SE (n=2). Means with different letters in the same column are significantly different (P<0.05). NB: UYSP & PYSP (Unpeeled and peeled Yellow Sweet Potato), UWSP & PWSP (Unpeeled and peeled White Sweet Potato) and UOSP & POSP (Unpeeled and peeled Orange Sweet Potato), UD (undetected).

4.2.3. Zinc content

The zinc content of three sweet potato varieties was significantly affected (P<0.05) by processing, variety and their interaction. All the investigated sweet potato cultivars were significantly varied (Table 4.2) in their zinc content and the mean value ranged from 1.14-1.97mg/100g in unpeeled and 0.68-0.93mg/100g in peeled condition. The mean zinc content of yellow, white and orange sweet potato varieties were 1.14, 1.97 and 1.30mg/100g and 0.68, 0.79 and 0.93mg/100g for unpeeled and peeled conditions, respectively. White and orange sweet potato cultivars contain the highest zinc content in unpeeled and peeled conditions, respectively while yellow sweet potato variety contains the lowest zinc content in both unpeeled and peeled conditions. Zinc content is generally low in all investigated sweet potato cultivars; a similar observation had been reported by Elkins (1979) and Lopez *et al.* (1980) that the average level of

zinc content in different sweet potato cultivars was varied from cultivar to cultivar and the observed average value ranged as low as 0.26-0.27 (mg/100g). Similar to other minerals, peeling was significantly decreased ($P<0.05$) the mean zinc content of all studied sweet potato varieties even though the zinc content in both unpeeled and peeled cases can be considered low. A similar result had been reported by ENV/JM/MONO (2010) that sweet potato contains higher level of zinc in unpeeled (1.30mg/100g) condition than that of peeled (0.6–1.2mg/100g) condition.

4.2.4. Phosphorus content

The phosphorus content of three sweet potato cultivars was significantly influenced ($P<0.05$) by processing, variety and their interaction. The mean values for phosphorus content among three sweet potato cultivars with different processing methods (Table 4.2) was indicated statistically significant variations; ranged from 19.22-24.50mg/100g in unpeeled condition and 15.70-21.80mg/100g in peeled condition. Result shows that the mean phosphorus content of yellow, white and orange sweet potato varieties was 19.22, 24.50 and 22.11mg/100g and 15.70, 21.80 and 20.67mg/100g for unpeeled and peeled roots, respectively. White sweet potato cultivar had the highest value of phosphorus content in both unpeeled and peeled conditions while the lowest value was observed in yellow sweet potato variety in both unpeeled and peeled root samples. A similar finding had been reported by Elkins (1979) and Lopez *et al.* (1980) that the level of phosphorus content is varied from cultivar to cultivar and the observed average value was 39.2-48.9(mg/100g). In some sweet potato cultivars, high level of average phosphorus(115.4 mg/100g) content had been reported by (Purcell *et al.*, 1989). On the other hand, peeling was significantly decreased ($P<0.05$) the mean phosphorus content of all studied sweet potato varieties; a similar idea was observed by ENV/JM/MONO (2010). This variation may be contributed by similar reasons that are discussed above for other minerals.

4.2.5. Magnesium content

The magnesium content of three sweet potato varieties was determined only in their root samples unpeeled cases (due to shortage of materials) and the mean value ranged from 3.00-5.98mg/100g. It was investigated that the mean magnesium content of yellow, white and orange sweet potato varieties were 5.86, 5.98 and 3.0mg/100g, respectively. The mean magnesium content of orange sweet potato variety was significantly ($P<0.05$) lower than that of both yellow

and white sweet potato varieties. On the other hand, white sweet potato variety contains higher level of mean magnesium value than that of yellow sweet potato variety but the value was not significantly different ($P>0.05$) from each other. Generally, the magnesium content of all varieties in this investigation can be considered low next to zinc among the above discussed minerals. A similar idea had been reported by Elkins (1979) and Lopez *et al.* (1980) that the level of magnesium content is varied from cultivar to cultivar and the observed average value was 18.3-22.2 (mg/100g). In some sweet potato cultivars, the level of average magnesium (12.20-30.40mg/100g) content had been reported by Ukom *et al.*, (2009). The variations in magnesium content might be contributed cultivars, climate, soil types, location and other factors.

4.3. Antinutritional factors of yellow, white and orange fleshed sweet potato cultivars

Three sweet potato varieties in their raw roots unpeeled and peeled conditions for antinutritional factors such as phytate, phytate mineral molar ratio, tannin and oxalate content were analyzed and the average results were presented in Table 4.3.

4.3.1. Phytate and phytate mineral molar ratio

The phytate content of three sweet potato cultivars was significantly affected ($P<0.05$) by processing, variety and their interaction. The mean value of phytate in yellow, white and orange sweet potato varieties were 111.43, 93.37 and 95.15mg/100g and 78.38, 49.35 and 77.75mg/100g for unpeeled and peeled conditions, respectively. The mean values for phytate content among three sweet potato cultivars with different processing methods (Table 4.3) indicated statistically significant variations; ranged from 93.37-111.43mg/100g in unpeeled and 49.35-78.38mg/100g in peeled root samples. The mean phytate content of yellow sweet potato variety was significantly ($P<0.05$) higher than that of both orange and white sweet potato varieties in both unpeeled and peeled conditions while significantly the lowest value was observed in white sweet potato cultivar in both unpeeled and peeled conditions. This variation might be attributed by cultivar difference, since all studied sweet potato cultivars were collected from the same environment.

On the other hand, peeling was significantly decreased ($P<0.05$) the mean phytate content of all studied three sweet potato cultivars. This is expected because more phosphorus is accumulated in

the outer skin layer of sweet potato root than that of inner flesh layer; hence phytate is natural occurring phosphorus compound.

The mean value of phytate: calcium molar ratio in the present study was 0.91, 0.90, 0.74 and 0.51 for unpeeled yellow sweet potato, peeled yellow sweet potato, unpeeled white sweet potato and peeled white sweet potato cultivars, respectively which were higher than the reported critical molar ratio (0.24) of phytate: calcium, indicating that absorption of calcium was adversely affected by phytate in these roots. But in case of both unpeeled (0.12) and peeled (0.11) orange sweet potato variety, the value was found lower than the reported critical molar ratio of phytate: calcium, indicating that absorption of calcium was not adversely affected by phytate in orange sweet potato roots. However, sweet potato root is consumed in its boiled state; this might reduce phytate level and enhance the bioavailability of calcium in yellow and white sweet potato varieties. All other calculated molar ratios in this study such as; Phytate: iron, phytate: zinc and [phytate x calcium]: zinc molar ratios for all sweet potato varieties in their unpeeled and peeled conditions were found less (Table 4.3) than their reported critical values, this indicates that absorption of iron and zinc from all studied sweet potato varieties were not inhibited by phytate and as a result these minerals in all roots are bioavailable.

4.3.2. Oxalate content

The oxalate content of three sweet potato cultivars was investigated only in unpeeled case (due to shortage of materials) and the mean value ranged from 3.50-8.80mg/100g (Table 4.3). The observed level of oxalate in yellow, white and orange sweet potato varieties was 8.80, 3.50 and 5.71mg/100g, respectively. The mean oxalate content of yellow sweet potato variety was significantly ($P<0.05$) higher than that of both orange and white sweet potato varieties. Similarly, the mean oxalate content of orange sweet potato variety was significantly ($P<0.05$) higher than that of white sweet potato varieties. This observed variation among three sweet potatoes might be attributed by cultivar difference. Oxalates can have a harmful effect on human nutrition and health, especially by reducing calcium absorption and aiding the formation of kidney stones (Noonan and Savage, 1999). However, the oxalate level observed in this study is low and also in recommended range for patients with calcium oxalate kidney stones if they consume up to 600g of any studied sweet potato cultivars per day; as patients are advised to limit their intake of foods with a total intake of oxalate not exceeding 50–60 mg per day (Massey *et al.*, 2001).

Oxalate like phytate binds minerals such as calcium and magnesium and interfere with their metabolism. The importance of oxalate content of an individual plant product in limiting total dietary calcium availability is of significance only when the ratio of oxalate: calcium is greater than one (Frontela *et al.*, 2009). Under this circumstance, the oxalate has potential to complex, not only the calcium contained in the plant, but also that derived from other food sources (Davis and Olpin, 1979). The oxalate: calcium values of YSP, WSP and OSP was 0.53, 0.20 and 0.06, respectively. These values were lower than the reported critical molar ratio (1.0) of oxalate: calcium, indicating that absorption of calcium not adversely affected by oxalate in all studied sweet potato varieties.

Table 4.3 Antinutritional factors (mg/100g) and phytate mineral molar ratios of yellow, white and orange fleshed sweet potato varieties

Variety	Phytate	Oxalate	Tannin	Phy:Ca	Phy:Fe	Phy:Zn	[PhyxCa]:Zn
UYSP	111.43±0.04 ^a	8.80±0.02 ^a	34.38	0.91±0.001 ^a	0.83±0.005 ^a	9.67±0.8 ^b	0.018±0.005 ^b
UWSP	93.37±0.01 ^c	3.50±0.04 ^c	B.D.L	0.71±0.001 ^b	0.59±0.00 ^c	4.70±0.0 ^f	0.01±0.00 ^b
UOSP	95.15±0.09 ^b	5.71±0.08 ^b	B.D.L	0.12±0.00 ^d	0.53±0.00 ^d	7.39±0.19 ^d	0.09±0.005 ^a
PYSP	78.38±0.01 ^d	UD	B.D.L	0.90±0.00 ^a	0.77±0.005 ^b	11.90±0.00 ^a	0.015±0.005 ^b
PWSP	49.35±0.03 ^f	UD	B.D.L	0.51±0.005 ^c	0.46±0.03 ^c	6.53±0.29 ^c	0.01±00 ^b
POSP	77.75 ±0.01 ^c	UD	B.D.L	0.11±0.005 ^c	0.58±0.005 ^c	8.15±0.28 ^c	0.10±0.005 ^a

Reported values are the mean ±SE (n=2). Means with different letters in the same column are significantly different (P<0.05). NB: UYSP& PYSP (Unpeeled and peeled Yellow Sweet Potato), UWSP&PWSP (Unpeeled and peeled White Sweet Potato) and UOSP&POSP (Unpeeled and peeled Orange Sweet Potato), UD (undetected), B.D.L. (below detection levels).

4.3.3. Tannin content

The tannin content in unpeeled and peeled root samples of three sweet potato cultivars was analyzed. The mean value of tannin content was 34.38 mg/100g in unpeeled yellow sweet potato cultivar and the value was below detection level in unpeeled and peeled white sweet potato variety, unpeeled and peeled orange sweet potato variety and peeled yellow sweet potato variety (Table 4.3). This result indicates that the level of tannin content is absent or insignificant in three investigated sweet potato cultivars except unpeeled condition of yellow sweet potato variety. It was also observed that tannin is accumulated in the outer skin layer of yellow sweet potato variety and it was removed by peeling with the outer skin layer of the root (Table 4.3). The

presence of tannin only in yellow sweet potato variety might be contributed by the presence of polyphenolic compound such as flavonoids (quercetin, $C_{15}H_{10}O_7$) which found in yellow sweet potato varieties (Guan *et al.*, 2006) and the absence of tannin in white and orange sweet potato varieties might be lack of these compounds in their roots.

The beneficial or antinutritional property of tannin depends on its amount in the diet. The toxicity effects of the tannin may not be significant since the total acceptable tannic acid daily intake for a man is 560mg (Anonymous, 1973). The current result shows that if a man daily consumes up to 1900 grams of unpeeled yellow sweet potato roots and any amount of unpeeled and peeled white sweet potato, unpeeled and peeled orange sweet potato and peeled yellow sweet potato roots, the level of tannin in these roots will not cause the toxicity effect to man.

4.4. Functional properties of composite flours

Functional properties of flour depends on the type of raw materials and methods of processing that determines product quality and process effectiveness. Functional properties also determine the application and use of food material for various food products (Adeleke and Odedeji, 2010). Hence, functional properties such as wet gluten and water absorption capacity of wheat and sweet potato composite flours were determined and results are presented in Table 4.4.

4.4.1. Wet gluten content

The mean wet gluten content of control and blend flours ranged from 16.87-30.44 g/100g (Table 4.4). The mean wet gluten content of wheat flour was 30.44 g/100g and it was absent (below in detection level) in sweet potato flour. Blending proportion significantly ($P<0.05$) affected mean wet gluten content of flours. The mean wet gluten content of blends was significantly ($p<0.05$) decreased from 30.44 to 16.87g/100g for 100% wheat flour to 25% SPF in blending proportion, respectively. The highest (30.44g/100g) and lowest (16.87g/100g) mean wet gluten content was observed in 100% wheat flour and 25% blend of sweet potato flour, respectively. Generally, the mean wet gluten content was significantly ($P<0.05$) decreased as blending ratio of sweet potato flour increased. This means that the sweet potato-wheat flour blends significantly decrease gluten content; this is because of gluten is absent in sweet potato flour and as blending ratio increases the wet gluten content decreases. Similar ideas were reported by (Kun-Lun *et al.*, 2009; Hamed *et al.*, 1973).

The water absorption results showed that increasing the proportion of sweet potato flour increased the absorption of water. Increase in water absorption lead to the weakened dough and decrease dough development and dough stability. This might be due to the dilution of wheat gluten as a result to addition of the sweet potato flour to wheat flour ; a similar trend also observed by Sukhcharn *et al.* (2008).

Table 4.4 Effect of blending ratio on functional properties of composite flours

Blending ratio	Wet gluten content (g/100g)	Water absorption capacity (ml/100g)
0%	30.44± 0.31 ^a	65.60± 0.42 ^f
5%	28.38± 0.15 ^b	73.20 ± 0.21 ^e
10%	25.24 ± 0.24 ^c	75.32 ± 0.13 ^d
15%	23.85 ± 0.12 ^d	81.60± 0.33 ^c
20%	19.88± 0.24 ^e	89.57 ± 0.23 ^b
25%	16.87 ± 0.09 ^f	91.61 ± 0.18 ^a

Reported values are the mean ±SE (n=3). Means with different letters in the same column are significantly different (P<0.05).

4.4.2. Water absorption capacity

The mean water absorption capacity of sweet potato flour and wheat flour was 194.58ml/g and 65.60ml/100g, respectively. The mean water absorption value of control and blend flours ranged from 65.60-91.61ml/100g (Table 4.4). Blending proportion significantly (P<0.05) affected mean water absorption capacity of flours. The mean water absorption capacity of blends was significantly (p<0.05) increased from 65.60 to 91.61ml/100g for 100% wheat four to 25% SPF blending proportion, respectively. The highest (91.61ml/100g) and lowest (65.60ml/100g) mean water absorption capacity was observed in 25% SPF supplemented blend and 0% SPF (100% wheat flour), respectively. Generally, the mean water absorption capacity was significantly (P<0.05) increased as blending proportion of sweet potato flour increased. Similar outcomes were investigated by (El-Zainy *et al.*, 2010; Sukhcharn *et al.*, 2008). This increment in water absorption capacity as SPF increase in blend ratio might be contributed by sweet potato flour; because moisture content was low in sweet potato flour than wheat flour which increases water absorption capacity as more sweet potato flour was supplemented in blending ratio.

4.5. Evaluation of quality parameters of bread

In this section the bread quality parameters such as loaf weight, loaf volume, loaf height and specific volume of breads were determined and results are presented in Table 4.5 and Figure 4.1.

Table 4.5 Effect of blending ratio on quality parameters of breads

Blending ratio	Volume (cm ³)	Weight (g)	Specific volume (cm ³ /g)	Height (cm)
0%	467.98± 1.80 ^a	84.09± 1.02 ^c	5.68± 0.08 ^a	5.77± 0.11 ^a
5%	461.08± 3.30 ^b	87.19 ± 0.53 ^d	5.29 ± 0.07 ^b	5.58 ± 0.04 ^a
10%	420.37 ± 2.90 ^c	89.32 ± 0.69 ^c	4.71± 0.06 ^c	4.92 ± 0.04 ^b
15%	357.87 ± 1.96 ^d	91.14± 0.17 ^b	3.93± 0.02 ^d	4.68± 0.10 ^c
20%	312.50± 1.48 ^e	92.79 ± 0.16 ^b	3.37 ± 0.12 ^e	4.22± 0.06 ^d
25%	260.47± 2.79 ^f	94.78 ± 0.15 ^a	2.75 ± 0.03 ^f	3.75 ± 0.03 ^e

Reported values are the mean ±SE (n=3). Means with different letters in the same column are significantly different (P<0.05).

4.5.1. Loaf weight

The dough (100g) was weighed before baking and the breads were weighed after baking. The average loaf weight of control and blend breads was ranged from 84.09-94.78g (Table 4.5). Blending ratio was showed significant increase (P<0.05) in mean weight of loaves as sweet potato flour increases in blending. Breads blended with 25% of sweet potato flour had the highest mean loaf weight (94.78g) while control breads had the least mean loaf weight (84.09g). Breads supplemented with 20% sweet potato flour had higher loaf weight than that of 15% SPF supplemented breads but they are not significantly different (P>0.05). All other breads are significantly different (P<0.05) from each other.

This increment in loaf weight of breads as sweet potato flour supplementation level increases in blending might be contributed by the higher water absorption capacity of sweet potato flour than that of wheat flour. These results were well agreed with findings of (Hamed *et al.*, 1973; Greene and Bovel-Brenjamin, 2004) who had found that the mean weight of loaf increases with the substitution level of sweet potato flour increased in their experimental breads. In addition, the average loaf weight of breads also had showed that control breads had highest moisture loss

(15.91%) while breads that were made from 25% SPF had the lowest (5.22%) moisture loss which reason out for highest loaf weight of the latter breads.

4.5.2. Loaf volume

Loaf volume is used as a criterion to measure the quality of fresh bread in research, quality control in industry and by consumers. Penfield and Campbell (1990) cited in Greene and Bovel-Brenjamin (2004). The average loaf volume of control and blended breads was ranged from 467.98-260.47cm³ (Table 4.5). Blending ratio resulted significant decrease ($P<0.05$) in mean volume of loaves as sweet potato flour increased in blending. Breads blended with 25% of sweet potato flour had the lowest mean loaf volume (260.47cm³) while control breads had the highest mean loaf volume (467.98cm³). The results in this study were agreed with other findings (El-Zainy *et al.*, 2010; Greene and Bovel-Brenjamin, 2004; Kun-Lun *et al.*, 2009; Hamed *et al.*, 1973).

The loaf volumes of the breads were expected because sweet potato is soft with low gluten content and rich in fiber and thus the loaf reflect the gluten content of the bread (Wu *et al.*, 2009 cited by El-Zainy *et al.*, 2010). Gluten is the main structure-forming protein in flour, is responsible for the elastic and extensible properties needed to produce good quality bread. Burton (1989) cited in Greene and Bovel-Brenjamin (2004) that amylolytic enzymes were responsible in potato-starch breakdown, producing simple sugars and more fermentable substrate for the yeast and thus increasing the fermentation rate. May be these amylolytic enzymes are also present in the sweet potato, this enzymatic action contributed to the observed loaf volumes.

4.5.3. Specific volume of loaf

The specific volume of loaf is the ratio of the loaf volume to loaf weight and the determined value ranged from 5.68-2.75cm³/g for control and blended breads (Table 4.5). The specific volume of breads in this study was significantly ($p<0.05$) decreased as blending ratio of SPF to WF increased in breads. Control breads had highest mean specific volume (5.68 cm³/g) while breads blended with 25% of SPF had the lowest mean specific volume (2.75cm³/g). Results of mean specific volume obtained in all experimental breads in this study was significantly different ($p<0.05$) from each other. This decrement in specific volume of breads can be resulted from

decreased wet gluten content with increased supplementation of SPF on WF that results in decreased loaf volume. Moreover the extra water absorption capacity of more SPF supplemented on WF which results in increased weight of final breads. Hence, specific volume is the ratio of loaf volume to loaf weight expected to be decreased. This result was agreed with El- Zainy *et al.* (2010).



Figure 4.1: Breads made from wheat flour and wheat-sweet potato composite flours

- | | | |
|-----------------------|-----------------------|-----------------------|
| A. Control (100%WF) | B. 95% WF and 5% SPF | C. 90% WF and 10% SPF |
| D. 85% WF and 15% SPF | E. 80% WF and 20% SPF | F. 75% WF and 25% SPF |

4.5.4. Loaf height

The average loaf height of control and blended breads ranged from 5.77-3.75cm (Table 4.5). Blending ratio was caused a significant decrease ($P<0.05$) in an average loaf height of breads as sweet potato flour supplementation level increased in blending. Control breads had highest mean loaf height (5.77cm) while breads supplemented with 25% of sweet potato flour had the lowest mean loaf height (3.75cm). Mean height of breads made with 5% SPF supplemented was not significant ($p>0.05$) in the loaf height when compared with the controlled breads. Generally, the effect of blending ratio of SPF on loaf height was similar to the effect obtained in loaf volume. This observed reduction in loaf height as supplementation of WF with SPF increased might be

contributed with less and less gluten level presence during dough formulation as more and more SPF was added in blending.

4.6. Sensory analysis of breads

The sensory attributes of breads made from WF substituted with varied ratios of SPF were investigated and the mean scores of evaluated sensory attributes of control and SPF supplemented breads were presented in Table 4.6.

4.6.1. Appearance

The visual appearance of any food is the first organoleptic sense of a consumer experiences. If supplemented food product has any change in appearance, consumers will more likely reject the product due to familiarization of the normal product (Olaoye *et al.*, 2006). The mean score of appearance of breads was ranged from 5.75-7.92 (Table 4.6). Blending ratio was caused a significant decrease ($p < 0.05$) in appearance of breads as supplement level of SPF increased. Control bread had the highest mean score for appearance (7.92) and had significant difference ($p < 0.05$) with 10% SPF (6.88), 15% SPF (6.08), 20% SPF (5.88) and 25% SPF (5.75) supplemented breads but not with 5% SPF (7.42) bread while 25% SPF supplemented breads scored the least mean appearance (5.75). Breads supplemented with 25% SPF (5.75) had least scored for appearance (least preferred by consumers) when compared with all experimental breads even though the mean score appearance of 25% SPF bread did not show significant difference ($p > 0.05$) when compared with both 15% SPF and 20% SPF supplemented breads. However, the mean appearance score results of all breads showed that those all experimental breads in this study were in acceptable range (above 5.75) by panelists. A similar idea was observed by Aniedu and Agugo (2010) and El- Zainy *et al.* (2010).

Table 4.6 Effect of blending ratio on sensory characteristics of breads

Blending ratio	Appearance	Aroma	Taste	Mouth Feel	Overall Acceptability
0%	7.92± 0.16 ^a	7.58± 0.16 ^a	7.46± 0.17 ^a	7.08± 0.18 ^a	7.17± 0.21 ^a
5%	7.42± 0.17 ^{ab}	7.25 ± 0.24 ^{ab}	7.13 ± 0.30 ^{ab}	6.88 ± 0.21 ^a	6.79± 0.28 ^{ab}
10%	6.88 ± 0.18 ^b	6.83 ± 0.24 ^b	6.83± 0.21 ^{ab}	6.00 ± 0.23 ^b	6.54 ± 0.20 ^{abc}
15%	6.08 ± 0.29 ^c	6.25± 0.30 ^c	6.67± 0.29 ^{bc}	5.88± 0.23 ^{bc}	6.17± 0.25 ^{bc}
20%	5.88± 0.19 ^c	6.33 ± 0.18 ^c	6.71 ± 0.21 ^{bc}	5.54± 0.27 ^{bc}	5.83± 0.23 ^{cd}
25%	5.75± 0.28 ^c	6.46 ± 0.27 ^c	6.33 ± 0.28 ^c	5.21 ± 0.28 ^c	5.38 ± 0.34 ^d

Reported values are the mean ±SE (n=24). Means with different letters in the same column are significantly different (P<0.05).

4.6.2. Aroma

The mean score of aroma of breads ranged from 6.46-7.58 (Table 4.6). Control bread had the highest mean score in aroma (7.58) while 25% SPF supplemented breads scored the least mean aroma (6.46). The effects of blend ratio of SPF on aroma indicate similar to the effects observed on appearance in all experimental breads. Mean scores of aroma of breads made with 5% SPF did not show a significant difference ($p > 0.05$) in the aroma when compared with both the control and 10% SPF supplemented breads. The mean score aroma of breads made from 15%, 20% and 25% SPF supplemented breads did not show any significant difference ($p > 0.05$) however, bread made from 25% SPF (6.46) scored higher value than those with 20% SPF (6.33) and 15% SPF (6.25) supplemented breads. This result shows that the average mean score of aroma obtained in all breads were above 6 (like slightly) suggesting that they are acceptable range by consumers. This result was well agreed with reported value of EI- Zainy *et al.* (2010).

4.6.3. Taste

The observed mean score of taste in experimental breads ranged from 6.33- 7.46 (Table 4.6). Control bread had the highest mean score in taste (7.46) and had significant difference ($p < 0.05$) with 15% SPF (6.67), 20% SPF (6.71) and 25% SPF (6.33) supplemented breads but not with those breads made with 5% SPF (7.13) and 10% SPF (6.83) supplemented breads. Breads supplemented with 20% SPF (6.71) more preferred than both 15% SPF (6.67) and 25% SPF (6.33) even though the mean score taste of those three breads did not show significant difference

($P>0.05$). Breads made with 25% SPF supplemented least preferred by panelists when compared with all other breads. However, the average mean score of taste for all breads were above 6 (like slightly), suggesting that they were accepted by consumers. The present finding was agreed with the works of Sukhearn *et al.* (2008) who found the mean score of taste reduced significantly with increased level of sweet potato flour on wheat flour in their cookies.

4.6.4. Mouth Feel

The mean score of mouth feel of breads ranged from 5.21-7.08 (Table 4.6). Blending ratio caused a significant decrease ($p<0.05$) in mean score of mouth feel of breads as supplement level of SPF increased. Control bread had the highest mean score in mouth feel (7.08) and had significant difference ($p<0.05$) with 10% SPF, 15% SPF, 20% SPF and 25% SPF supplemented breads but not with 5% SPF supplemented bread. Breads made with 25% SPF supplemented least preferred by panelists when compared with all other breads although those breads were not significantly different from 15% SPF (5.88) and 20% SPF (5.54) supplemented breads. A similar result had been reported by Olaoye *et al.* (2006).

4.6.5. Overall acceptability

The mean overall acceptability of breads ranged from 5.38-7.17 (Table 4.6). Control bread had the highest mean overall acceptability (7.17) and had significant difference ($p<0.05$) with 15% SPF, 20% SPF and 25% SPF supplemented breads but not with those breads made with 5% SPF and 10% SPF supplemented breads. Breads prepared from 5% SPF supplemented was more preferred by consumers than both 10% SPF and 15% SPF even though the mean scores of those three breads did not show a significant difference ($P>0.05$). Breads made with 25% SPF supplemented were the least preferred by consumers when compared with all other breads but the mean acceptability of breads made with 25% SPF and 20% SPF was not show any significant difference ($p>0.05$).

Breads made at 15%, 20% and 25% sweet potato substitution levels were significantly ($P<0.05$) different in some of the attributes tested (appearance, aroma, taste and mouth feel) from the control bread hence control bread being more preferred by the panelists. However, at 5% and 10% SPF substitution levels there were no significant ($P>0.05$) difference in the mean acceptability of control bread and sweet potato supplemented breads. The panelists mean score

test revealed that the control bread was scored higher in all the tested attributes. However, this does not mean that other bread samples were not acceptable, even at 25% substitution level the panelists seem to like the aroma and taste of bread produced from sweet potato and wheat flour blend. Despite the fact that control bread was more preferred to sweet potato supplemented breads, the average mean score of overall acceptability of up to 15% SPF composite breads are above 6 (like slightly) suggesting that they are acceptable range by consumers. This higher sensory attribute scoring for control bread compared with sweet potato and wheat flours composite breads could be due to the familiarization of the consumers to the normal wheat bread (Olaoye *et al.*, 2006). This result was agreed with previous works of (Aniedu and Agugo, 2010; Greene and Bovell-Benjamin, 2004; Sukhcharn *et al.*, 2008).

4.7. Nutritional composition

4.7. 1. Nutritional composition of flours

Table 4.7 Chemical composition of orange sweet potato flour and wheat flour (on dry weight basis)

Constituents (%)	Wheat flour	Sweet potato flour
Moisture(g)	12.38± 0.04 ^a	8.37± 0.02 ^b
Protein(g)	11.63 ±0.18 ^a	2.74 ± 0.01 ^b
Fat(g)	1.97 ± 0.02 ^a	1.12 ± 0.01 ^b
Crud Fiber(g)	1.83 ± 0.01 ^b	3.83±0.04 ^a
Ash(g/100g)	0.78± 0.15 ^b	4.30 ± 0.03 ^a
Carbohydrate(g)	84.04± 0.18 ^b	88.00±0.02 ^a
Total Energy (Kcal)	400.53± 0.14 ^a	373.00±0.15 ^b
Calcium(mg)	27.41 ± 0.02 ^b	45.54 ± 0.01 ^a
Phosphorus(mg)	24.66 ± 0.01 ^a	20.68 ± 0.01 ^b
Iron (mg)	3.65 ± 0.02 ^b	11.46 ± 0.11 ^a
Zinc(mg)	0.69±0.01 ^b	0.93±0.01 ^a
Phytate(mg)	158.38± 0.24 ^a	77.74 ± 0.01 ^b
WAC(ml/100g)	65.60 ^b	194.58 ^a

Reported values are the mean ± SE (n=3).
Means with different letters in the same rows are significantly different (p<0.05)

The mean values for proximate, minerals and phytate composition of wheat flour and sweet potato flour were calculated in 100g of flours and the obtained results are presented in Table 4.7. Sweet potato flour compared to wheat flour contains lower level of crude protein, crude fat, moisture, total energy and higher level of total ash, crude fiber and total carbohydrate content. Considering to minerals and phytate composition, sweet potato flour has higher level of calcium, iron and zinc and lower level of phosphorus and phytate than wheat flour. This result indicates that there is significantly compositional difference between sweet potato flour and wheat flour in their levels of proximate, minerals and phytate content. Therefore, blending of sweet potato flour to wheat flour will contribute to increase nutrients which were lower in one of the component of composite flours of breads.

4.7.2. Nutritional composition of breads

4.7.2.1. Proximate composition of breads

The mean values of proximate composition such as moisture, crude protein, crude fat, crude fiber, total ash, total carbohydrate and total energy of control and different levels of sweet potato flour supplemented breads were determined and the results were indicated in Table 4.8. Moreover, the effects of blend ratio on the nutritional status of the formulated breads were discussed in this section.

Table 4.8 Effect of blending ratio on proximate composition (g/100g) of breads

Blend ratio	Moisture*	Protein	Fat	Ash	Fiber	CHO**	T.E***
0%	30.77± 0.31 ^f	11.17± 0.01 ^a	1.73± 0.02 ^a	1.59± 0.01 ^f	1.76± 0.01 ^f	83.74± 0.01 ^{cd}	395.25± 0.17 ^a
5%	32.81± 0.04 ^e	10.86 ± 0.04 ^b	1.48 ± 0.03 ^b	1.82 ± 0.03 ^e	1.96± 0.01 ^e	83.87± 0.09 ^e	392.29± 0.29 ^b
10%	33.47 ± 0.02 ^d	10.66 ± 0.06 ^b	1.40± 0.04 ^{bc}	2.16 ± 0.04 ^d	2.22 ± 0.01 ^d	83.55 ± 0.03 ^d	389.47 ± 0.38 ^c
15%	34.90 ± 0.02 ^c	9.94± 0.02 ^c	1.36± 0.01 ^{cd}	2.40± 0.01 ^c	2.43± 0.01 ^c	83.88± 0.05 ^e	387.51± 0.06 ^d
20%	35.49± 0.03 ^b	9.31 ± 0.06 ^d	1.32 ± 0.02 ^d	2.58± 0.02 ^b	2.63± 0.02 ^b	84.16± 0.07 ^b	385.73± 0.22 ^e
25%	37.15± 0.03 ^a	8.34 ± 0.13 ^e	1.23 ± 0.02 ^e	2.83 ± 0.02 ^a	2.75± 0.01 ^a	84.85± 0.17 ^a	383.85± 0.08 ^f

Reported values are the mean ±SE (n=3). Means with different letters in the same column are significantly different (P<0.05). *Wet basis, **Total carbohydrate, ***Total energy (Kcal/100g).

4.7.2.1.1. Moisture content

The mean moisture content of breads ranged from 30.77-37.15g/100g (Table 4.8). Breads at 25% SPF substitution level had the highest mean moisture value (37.15g/100g) while the control one had the least value (30.77g/100g). The mean moisture content of all breads in this study were significantly different ($p<0.05$) from each other. Statistical analysis showed that the mean moisture content of all experimental breads were significantly increased ($p<0.05$) as substitution levels of sweet potato flour increased. This increment could be attributed to the water binding capacity of sweet potato flour. As it can be seen from the results of WAC analysis of sweet potato and wheat flour, the water binding capacity of sweet potato flour was observed to be high to cause a greater water holding capacity of the sweet potato flour than the wheat flour. This is the reason why the moisture content of the breads increased with an increase in the sweet potato flour proportion. The present finding was consistent with reports of Aniedu and Agugo (2010).

4.7.2.1.2. Crude protein content

The mean protein content of breads ranged from 8.34-11.17g/100g (Table 4.8). Control bread had the highest mean protein content (11.17g/100g) while bread at 25% SPF substitution level had the least value (8.34g/100g). The mean protein content of breads were significantly decreased ($p<0.05$) as substitution levels of sweet potato flour increased. Breads at 5% SPF and 10% SPF substitution levels did not show significant difference ($p>0.05$) in mean protein content even though the mean protein value decreases with the supplementation levels of SPF increased. Except for 5% SPF and 10% SPF substituted breads, the mean protein content of all other breads were significantly different ($p<0.05$) from each other. Low protein content was observed with all sweet potato supplemented breads compared to the control bread. This could be as a result of the low protein content in sweet potato flour than wheat flour. The present finding was consistent with reports of (Aniedu and Agugo, 2010; El- Zainy *et al.*, 2010; Ifie, 2011) who found that the protein content in bread products increases with corresponding increase in the ratio of SPF supplementation in wheat flour.

4.7.2.1.3. Crude fat content

Table 4.8 shows the mean fat content of breads ranging from 1.23-1.73g/100g. Control bread had the highest mean fat content (1.73g/100g) while bread at 25% SPF substitution level had the least value (1.23g/100g). The mean fat content of breads were significantly decreased ($p<0.05$) as substitution levels of sweet potato flour increased. Breads with 5% SPF and 10% SPF, 10% SPF and 15% SPF, 15% SPF and 20% SPF substitution levels did not show significant difference ($p>0.05$) in mean fat content to each other even though the mean fat value decreases with the supplementation levels of SPF increased. These reductions in mean fat content of breads observed in current study due to sweet potato flours contain low fat when compared to wheat flours. These results were well agreed with the findings of (Aniedu and Agugo, 2010; Ifie, 2011).

4.7.2.1.4. Crude fiber content

The mean fiber content of breads ranged from 1.76-2.75g/100g (Table 4.8). Control bread had the least mean fiber content (1.76g/100g) while bread at 25% SPF substitution level had the highest value (2.75g/100g). The mean fiber content of breads were significantly increased ($p<0.05$) as substitution levels of sweet potato flour increased. This increment in mean fiber content of breads could be due to the high quantity of fiber in sweet potato flour than that of wheat flour. The present findings were consistent with results of (Aniedu and Agugo, 2010; El-Zainy *et al.*, 2010; Ifie, 2011) who had been presented that the fiber content in bread products increases with corresponding increase in the ratio of SPF supplementation in wheat flour.

4.7.2.1.5. Total ash content

The mean ash content of breads ranged from 1.59-2.83g/100g (Table 4.8). All blended breads had significantly higher ($p<0.05$) value of mean ash content when compared with the control bread. The effects of blend ratio was significantly increased ($p<0.05$) in mean ash content with SPF supplementation level on wheat flour increased. Control bread had the lowest the mean ash content (1.59g/100g) while bread at 25% SPF substitution level had the highest value (2.83g/100g). This increment in mean ash content of breads might be attributed by sweet potato flour; as sweet potato flour contains high ash level when compared to wheat flour. These results were in full agreement with results reported by (Aniedu and Agugo, 2010; El-Zainy *et al.*,

2010; Ifie, 2011) who investigated that the ash content in bread products increases with corresponding increase in the ratio of SPF supplementation in wheat flour.

4.7.2.1.6. Total carbohydrate content

The mean carbohydrate content of breads ranged from 83.55-84.85g/100g (Table 4.8). The mean carbohydrate content of breads in this finding was increased even though some irregularity value was also happened. Control bread did not show significant difference ($p>0.05$) in mean carbohydrate content up to 15% SPF substitution level but was significantly different ($p<0.05$) with breads made up of 20% and 25% SPF substitution levels. The highest and lowest mean carbohydrate content were observed with breads supplemented at 25% SPF and 5% SPF levels, respectively. This increment might be attributed by sweet potato flour; as sweet potato flour contains high carbohydrate level when compared to wheat flour. A similar result had been reported by Ifie (2011).

4.7.2.1.7. Total energy content

The mean total energy content of breads ranged from 383.85- 395.25Kcal/100g (Table 4.8). The mean total energy content of breads was significantly decreased ($p<0.05$) with SPF substitution level increased. Control bread had the highest value of energy (395.25Kcal/100g) and was significantly different ($p<0.05$) compared to all other SPF supplemented breads while bread supplemented with 25% SPF had the least score (383.85Kcal/100g). This decrement in total energy of breads as the ratio of SPF increased in the blend, therefore, might be attributed by less energy content of sweet potato flour.

4.7.2.2. Mineral content of breads

Breads from different blending ratio of sweet potato flour and wheat flour were analyzed for mineral contents (calcium, phosphorus, iron and zinc) and the results are presented in Table 4.9.

4.7.2.2. 1. Calcium content

The mean calcium content of breads ranged from 21.08-31.42mg/100g (Table 4.9). Control bread had the least mean calcium content (21.08mg/100g) while bread at 25% SPF substitution level had the highest value (31.42mg/100g). The mean calcium content of breads were

significantly increased ($p<0.05$) as substitution levels of sweet potato flour increased. Higher score of calcium content was observed with all sweet potato supplemented breads compared to the control bread. This could be due to high content of calcium in sweet potato flour than wheat flour. This result was consistent with finding of El- Zainy *et al.* (2010) who revealed that calcium content in bread products increases with corresponding increase in the ratio of SPF supplementation in wheat flour.

Table 4.9 Effect of blending ratio on mineral composition of breads (mg/100g)

Blending ratio	Calcium	Phosphorus	Iron	Zinc
0%	21.08± 0.01 ^f	19.23± 0.02 ^a	2.92± 0.01 ^f	0.52± 0.01 ^c
5%	22.11± 0.01 ^e	19.12 ± 0.01 ^b	3.30± 0.01 ^e	0.56 ± 0.01 ^{cd}
10%	24.55 ± 0.02 ^d	18.78 ± 0.02 ^c	3.76± 0.02 ^d	0.59 ± 0.01 ^{cd}
15%	26.90 ± 0.01 ^c	18.42± 0.02 ^d	4.27± 0.01 ^c	0.62± 0.02 ^{bc}
20%	29.14± 0.01 ^b	17.98 ± 0.01 ^e	4.65 ± 0.02 ^b	0.64± 0.02 ^b
25%	31.42± 0.01 ^a	17.51 ± 0.02 ^f	5.09± 0.01 ^a	0.68 ± 0.01 ^a

Reported values are the mean ±SE (n=2). Means with different letters in the same column are significantly different ($P<0.05$)

4.7.2.2. 2. Phosphorus content

The mean phosphorus content of breads ranged from 17.51-19.23mg/100g (Table 4.9). Control bread had the highest mean phosphorus content (19.23mg/100g) while bread at 25% SPF substitution level had the least value (17.51mg/100g). The mean phosphorus content of breads were significantly decreased ($p<0.05$) as substitution levels of sweet potato flour increased. Lower score of phosphorus content was observed with all sweet potato supplemented breads compared to the control bread. This decrement in phosphorus level of breads as the ratio of SPF increased in the blend, therefore, might be attributed by less phosphorus content of sweet potato flour.

4.7.2.2. 3. Iron content

The mean iron content of breads ranged from 2.92-5.09mg/100g (Table 4.9). Control bread had the least mean iron content (2.92mg/100g) while bread at 25% SPF substitution level had the highest value (5.09mg/100g). The mean iron content of breads were significantly increased

($p<0.05$) as substitution levels of sweet potato flour increased. Higher score of iron content was observed with all sweet potato supplemented breads compared to the control bread. This could be due to high content of iron in sweet potato flour than wheat flour. A similar result was observed by El- Zainy *et al.* (2010) who found that iron content in bread products increases with corresponding increase in the ratio of SPF supplementation in wheat flour.

4.7.2.2. 4. Zinc content

Low level of zinc content was observed in all investigated breads and the mean value ranged from 0.52-0.68mg/100g. Control bread had the least mean zinc content (0.52mg/100g) while bread at 25% SPF substitution level had the highest value (0.68mg/100g). Breads with 0% SPF (100% wheat flour) and 5% SPF, 5% SPF and 10% SPF, 10% SPF and 15% SPF, 15% SPF and 20% SPF substitution levels did not show significant difference ($p>0.05$) in mean zinc content to each other even though the mean zinc value increases with the blending ratio of SPF increased. Generally, the mean zinc content of breads were significantly increased ($p<0.05$) as blending ratio of sweet potato flour increased. This could be due to high content of zinc in sweet potato flour than wheat flour; a similar result was investigated by El- Zainy *et al.* (2010).

4.7.2.3. Phytate content and phytate mineral molar ratios of breads

The mean values of antinutritional factor such as phytate content and phytate mineral molar ratios of control and different levels of sweet potato flour supplemented breads were determined and results are tabulated in Table 4.10.

4.7.2.3.1. Phytate content

The mean phytate content of breads ranged from 67.43- 98.88mg/100g (Table 4.10). The mean phytate content of breads was significantly decreased ($p<0.05$) with SPF substitution levels increased. Control bread had the highest value of phytate (98.88mg/100g) and was significantly different ($p<0.05$) compared to all other SPF supplemented breads while bread supplemented with 25% SPF had the least value (67.43mg/100g). This decrease could be attributed to the level of phytate in sweet potato flour than wheat flour. As it can be seen from the results of phytate analysis of sweet potato and wheat flour, the phytate content of sweet potato flour was observed

to be low compared with wheat flour. This is the reason why the phytate content of the breads decreased with an increase in the sweet potato flour proportion.

4.7.2.3.2. Phytate: Calcium molar ratio

The mean phytate: calcium molar ratio of breads ranged from 0.14-0.29 (Table 4.10). The mean phytate: calcium molar ratio of breads was significantly decreased ($p<0.05$) with SPF substitution levels increased. Control bread had the highest value of phytate: calcium molar ratio (0.29) and was significantly different ($p<0.05$) compared to all other SPF supplemented breads while bread supplemented with 25% SPF had the least value (0.14). This decrease could be attributed to the low and high level of phytate and calcium in sweet potato flour than wheat flour. Phytic acids markedly decrease calcium bioavailability and the phytate: calcium molar ratio has been proposed as an indicator of calcium bioavailability.

The phytate: calcium molar ratios >0.24 , indicative of poor calcium bioavailability (Norhaizan and Faizadatul, 2009). The phytate: calcium molar ratio in the present study for control and 5% SPF substituted breads were higher than the reported critical level; this indicates that absorption of calcium adversely affected by phytate in these breads. But in case of other breads (10%-25% SPF substituted breads) the value was lower than the reported critical level, which shows that absorption of calcium not affected by phytate in these breads.

Table 4.10 Effect of blending ratio on phytate and phytate mineral molar ratios of breads

Blending ratio	Phytate				[Phy×Ca]:Zn (mg/100g)
	(mg/100g)	Phy:Ca	Phy:Fe	Phy:Zn	
0%	98.88±0.34 ^a	0.29±0.01 ^a	2.89±0.01 ^a	18.82±0.41 ^a	0.099±0.001 ^a
5%	89.94±0.65 ^b	0.25±0.01 ^b	2.31±0.02 ^b	16.03±0.10 ^b	0.094±0.004 ^a
10%	87.29±0.65 ^c	0.22±0.01 ^c	1.96±0.00 ^c	14.67±0.05 ^c	0.093±0.003 ^a
15%	75.83±0.64 ^d	0.18±0.01 ^d	1.52±0.02 ^d	12.12±0.49 ^d	0.083±0.004 ^b
20%	72.21±0.65 ^e	0.16±0.01 ^e	1.32±0.02 ^e	11.19±0.19 ^{de}	0.082±0.002 ^b
25%	67.43±0.33 ^f	0.14±0.01 ^f	1.13±0.01 ^f	10.25±0.05 ^e	0.081±0.001 ^b

Reported values are the mean ± SE (n=3). Means with different letters in the same columns are significantly different ($P<0.05$)

4.7.2.3.3. Phytate: Iron molar ratio

The mean phytate: iron molar ratio of breads ranged from 1.13-2.89 (Table 4.10). The mean phytate: iron molar ratio of breads was significantly decreased ($p<0.05$) with SPF substitution levels increased. Control bread had the highest value of phytate: iron molar ratio (2.89) and was significantly different ($p<0.05$) compared to all other SPF supplemented breads while bread supplemented with 25% SPF had the least value (1.13). This decrease could be attributed to the low and high level of phytate and iron in sweet potato flour than wheat flour. The phytate: iron molar ratio >1 , indicative of poor iron bioavailability (Norhaizan and Faizadatul, 2009). The phytate: iron molar ratio in the present study for all breads were higher than the reported critical value, which implies the absorption of iron from all experimental breads were found inhibited by phytate and as a result the bioavailability of iron is poor in these breads.

4.7.2.3.4. Phytate: Zinc molar ratio

The mean phytate: zinc molar ratio of breads ranged from 10.25-18.82 (Table 4.10). The mean phytate: zinc molar ratio of breads was significantly decreased ($p<0.05$) with SPF substitution levels increased. Control bread had the highest value of phytate: zinc molar ratio (18.82) and was significantly different ($p<0.05$) compared to all other SPF supplemented breads while bread supplemented with 25% SPF had the least value (10.25). This decrease could be attributed to the low and high level of phytate and zinc in sweet potato flour than wheat flour. The phytate: zinc molar ratios >15 , indicative of poor zinc bioavailability (Norhaizan and Faizadatul, 2009). The phytate: zinc molar ratio in the present study for control and 5% SPF substituted breads were higher than the reported critical level, indicating that absorption of zinc was found adversely affected by phytate in these breads. But in case of other breads (10%-25% SPF substituted breads) the value was found lower than the reported critical value, indicating that absorption of calcium was not affected by phytate in these breads.

4.7.2.3.5. [Phytate x Calcium]: Zinc molar ratio

The mean [phytate x calcium]: zinc molar ratio of breads ranged from 0.081-0.099mg/100g (Table 4.10). Generally, the mean [phytate x calcium]: zinc molar ratio of breads was significantly decreased ($p<0.05$) with SPF substitution levels increased. Control bread had the

highest value of [phytate x calcium]: zinc molar ratio (0.099) and was significantly different ($p<0.05$) compared to 15%, 20% and 25% SPF supplemented breads but not significantly different compared to 5% and 10% SPF supplemented breads. This decrease could be attributed to the low and high level of phytate and zinc in sweet potato flour than wheat flour. The potential effect of calcium on zinc absorption in the presence of high phytate intakes has led to the suggestion that the [phytate x calcium]: zinc molar ratio may be a better index of zinc bioavailability than the phytate: zinc molar ratio alone (Obah and Amusan, 2009). High calcium levels in foods can promote the phytate-induced decrease in zinc bioavailability when the [phytate x calcium]: zinc molar ratio greater than 200mg/100g (Norhaizan and Faizadatul, 2009). In this study, the values of [phytate x calcium]: zinc molar ratios of all breads were found less than the reported critical level. Therefore, bioavailability of zinc is not affected by calcium in the presence of phytate levels in all experimental breads.

5. Conclusion and Recommendations

5.1. Conclusion

This study has covered information on the nutritional and antinutritional status of yellow, white and orange fleshed sweet potato cultivars in their raw roots unpeeled and peeled conditions. It also attempted to investigate the possibility of using orange sweet potato flour for the production of breads by blending with wheat flour. Moreover, the effect of blending ratio of sweet potato flour and wheat flour on the nutritional, antinutritional, quality and sensory attributes of breads was investigated. Finally, functional properties of the composite flours were also studied.

The result showed that the nutritional and antinutritional contents of three sweet potato varieties were significantly varied due to cultivar variation, processing conditions and their interactions. Orange sweet potato variety contains the highest level of moisture, fat, ash, carbohydrate, energy, calcium and iron in unpeeled condition and fiber, moisture, fat, ash, calcium, iron and zinc in peeled condition. The protein content was least in orange sweet potato cultivar in both conditions. Yellow sweet potato variety contains the highest level of protein, phytate, phytate: calcium, Phytate: iron and Phytate: zinc molar ratios in both unpeeled and peeled conditions while fiber, oxalate and tannin value was highest in unpeeled condition. White sweet potato variety contains the highest and lowest levels of phosphorus and phytate in both unpeeled and peeled conditions and it was found in intermediate position for other nutrients. On the other hand, peeling was decreased the levels of moisture, protein, fiber, ash, carbohydrate, calcium, phosphorus, iron, zinc and phytate and increased the other parameters such as fat, carbohydrate and energy contents in their corresponding varieties. Among three sweet potato cultivars, this result has indicated that orange sweet potato variety is potentially good source of nutrients compared to other sweet potato varieties. Hence, orange sweet potato cultivar is selected for bread making.

Supplementation of orange sweet potato flour to wheat flour greatly decreased dough stability and loaf size (volume, specific volume and height) due to the dilution of gluten matrix in wheat flour. Composite flours have higher level of wet gluten content and lower level of water absorption capacity than control flour. Breads prepared from SPF supplemented flours had significantly increased levels of moisture, ash, fiber, carbohydrate, calcium, iron and zinc content

than control breads. This was due to the high levels of these nutrients in SPF compared to wheat flour. On the other hand, there was a decrease in protein, fat, energy and phosphorus levels of breads as substitution of SPF increased in blending ratio. Moreover, the phytate content and phytate mineral molar ratios of blended breads were also significantly decreased than control breads. Thus, supplementation of SPF can reduce phytate level, enhance mineral bioavailability and improve nutritional status of wheat breads.

Comprehensively, this result was indicated that supplementation of SPF to WF will greatly reduce phytate level, enhance mineral bioavailability and improve the nutritional status of wheat breads; particularly carbohydrate, ash, fiber, calcium, iron and zinc values. Nevertheless, all nutritionally rich food products may not be always desired to consumer acceptance. Results of sensory attributes in terms of appearance, aroma, taste, mouth feel and overall acceptability indicated that control breads were more preferred by consumers than SPF supplemented breads. However, breads made by using 15% SPF substituted accepted by consumers (scored above like slightly range), this leads to the conclusion that nutritional improved, antinutritional reduced and consumer acceptable breads can be prepared by supplementing up to 15% SPF in WF. In general, the result of this study will not only help consumers selectively cultivate and consume high nutritious sweet potato cultivar but also it provides the possibility of its flour substitution to wheat flour and to develop nutritional improved breads.

5.2. Recommendations

Based on the current study, the following recommendations are made:

- ◆ Since orange sweet potato variety is potentially good source of nutrients among three sweet potato varieties, more emphasis should be given for its cultivation in agricultural sectors as well as farmers land.
- ◆ It is highly recommended that sweet potato roots should be consumed in its unpeeled state: peeling of sweet potato roots removes most of nutrients that are important to human health.
- ◆ Traditional processing methods should be investigated in all varieties in order to observe effect of processes on nutritional and antinutritional factors.
- ◆ Breads production from sweet potato and wheat composite flours should be given emphasis and processors should be encouraged to utilize the potential nutrient source of sweet potato flour. Since such breads are a good source of dietary fiber, which may also be of benefit in the prevention of cardiovascular diseases and cancers.
- ◆ Since protein value is low in sweet potato cultivars, it is encouraged that sweet potato crop should be consumed along with legumes. Thus, farmers who cultivate sweet potato crop should also cultivate legumes in order to compensate protein value of sweet potato for their growing children.

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Appendices

Appendix-I: Score sheet for sensory evaluation of breads

Sample code: -----

Date: -----

Instruction: You are kindly requested to taste each of the six samples you are provided and choose the descriptor which, in your option, is the most applicable to the attributes being evaluated. Rinse your mouth with water provided after you have finished evaluating each sample and wait about three minutes before evaluating the next sample. Use for: Like extremely(9), Like Very much(8), Like moderately(7), Like slightly(6), Neither Like nor Dislike(5), Dislike Slightly(4), Dislike Moderately(3), Dislike Very much(2) and Dislike Extremely(1).

Category scale	Appearance	Aroma	Taste	Mouth Feel	Overall Acceptability
Like Extremely					
Like Very much					
Like Moderately					
Like Slightly					
Neither Like nor Dislike					
Dislike Slightly					
Dislike Moderately					
Dislike Very much					
Dislike Extremely					

Comments:-----

Thank you!

Appendix-II: Proximate composition of three sweet potato varieties

2.1. Moisture

Tests of Between-Subjects Effects

Dependent Variable: moisture

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	90.709(a)	5	18.142	85.825	.000
Intercept	63095.302	1	63095.302	298487.590	.000
Processing	17.376	1	17.376	82.202	.000
Variety	72.485	2	36.242	171.453	.000
Processing * Variety	.849	2	.424	2.008	.215
Error	1.268	6	.211		
Total	63187.279	12			
Corrected Total	91.978	11			

a. R Squared = .986 (Adjusted R Squared = .975)

2.2 Crude protein

Tests of Between-Subjects Effects

Dependent Variable: protein

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	21.428(a)	5	4.286	53.029	.000
Intercept	196.506	1	196.506	2431.505	.000
Processing	4.320	1	4.320	53.454	.000
Variety	15.598	2	7.799	96.504	.000
Processing * Variety	1.510	2	.755	9.340	.014
Error	.485	6	.081		
Total	218.419	12			
Corrected Total	21.913	11			

a. R Squared = .978 (Adjusted R Squared = .959)

2.3. Crude Fat

Tests of Between-Subjects Effects

Dependent Variable: fat

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	.655(a)	5	.131	63.870	.000
Intercept	6.780	1	6.780	3307.333	.000
Processing	.077	1	.077	37.463	.001
Variety	.575	2	.288	140.346	.000
Processing * Variety	.002	2	.001	.598	.580
Error	.012	6	.002		
Total	7.447	12			
Corrected Total	.667	11			

a. R Squared = .982 (Adjusted R Squared = .966)

2.4. Crude Fiber

Tests of Between-Subjects Effects

Dependent Variable: fiber

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	17.774(a)	5	3.555	631.948	.000
Intercept	238.610	1	238.610	42419.557	.000
Processing	12.221	1	12.221	2172.624	.000
Variety	2.613	2	1.307	232.286	.000
Processing * Variety	2.939	2	1.470	261.273	.000
Error	.034	6	.006		
Total	256.417	12			
Corrected Total	17.807	11			

a. R Squared = .998 (Adjusted R Squared = .997)

2.5. Ash

Tests of Between-Subjects Effects

Dependent Variable: Ash

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	5.591(a)	5	1.118	210.003	.000
Intercept	202.787	1	202.787	38082.142	.000
Processing	1.159	1	1.159	217.729	.000
Variety	4.371	2	2.185	410.387	.000
Processing * Variety	.061	2	.031	5.757	.040
Error	.032	6	.005		
Total	208.411	12			
Corrected Total	5.623	11			

a. R Squared = .994 (Adjusted R Squared = .990)

2.6. Carbohydrate

Tests of Between-Subjects Effects

Dependent Variable: Carbohydrate

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	54.366(a)	5	10.873	183.307	.000
Intercept	89977.401	1	89977.401	1516899.143	.000
Processing	38.880	1	38.880	655.465	.000
Variety	6.543	2	3.272	55.155	.000
Processing * Variety	8.943	2	4.471	75.380	.000
Error	.356	6	.059		
Total	90032.123	12			
Corrected Total	54.722	11			

a. R Squared = .993 (Adjusted R Squared = .988)

2.7. Energy

Tests of Between-Subjects Effects

Dependent Variable: Energy

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	318.448(a)	5	63.690	48.692	.000
Intercept	1656956.969	1	1656956.969	1266778.603	.000
Processing	156.313	1	156.313	119.505	.000
Variety	34.624	2	17.312	13.235	.006
Processing * Variety	127.511	2	63.756	48.743	.000
Error	7.848	6	1.308		
Total	1657283.266	12			
Corrected Total	326.296	11			

a. R Squared = .976 (Adjusted R Squared = .956)

Appendix-III: Mineral composition of three sweet potato variety

3.1. Calcium

Tests of Between-Subjects Effects

Dependent Variable: Calcium

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	4197.335(a)	5	839.467	799492.451	.000
Intercept	4740.983	1	4740.983	4515221.460	.000
Processing	10.305	1	10.305	9813.841	.000
Variety	4186.817	2	2093.409	1993722.437	.000
Processing * Variety	.214	2	.107	101.770	.000
Error	.006	6	.001		
Total	8938.324	12			
Corrected Total	4197.342	11			

a. R Squared = 1.000 (Adjusted R Squared = 1.000)

3.2. Phosphorus

Tests of Between-Subjects Effects

Dependent Variable: Phosphorus

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	89.594(a)	5	17.919	5231.763	.000
Intercept	5124.093	1	5124.093	1496085.667	.000
Processing	19.584	1	19.584	5717.978	.000
Variety	67.813	2	33.906	9899.696	.000
Processing * Variety	2.197	2	1.098	320.723	.000
Error	.021	6	.003		
Total	5213.708	12			
Corrected Total	89.614	11			

a. R Squared = 1.000 (Adjusted R Squared = 1.000)

3.3. Iron

Tests of Between-Subjects Effects

Dependent Variable: Iron

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	57.056(a)	5	11.411	32603.467	.000
Intercept	1631.001	1	1631.001	4660002.381	.000
Processing	35.226	1	35.226	100646.095	.000
Variety	21.248	2	10.624	30354.667	.000
Processing * Variety	.582	2	.291	830.952	.000
Error	.002	6	.000		
Total	1688.059	12			
Corrected Total	57.058	11			

a. R Squared = 1.000 (Adjusted R Squared = 1.000)

3.4. Zinc

Tests of Between-Subjects Effects

Dependent Variable: Zinc

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	2.198(a)	5	.440	2197.767	.000
Intercept	15.368	1	15.368	76840.167	.000
Processing	1.347	1	1.347	6733.500	.000
Variety	.449	2	.224	1121.792	.000
Processing * Variety	.402	2	.201	1005.875	.000
Error	.001	6	.000		
Total	17.567	12			
Corrected Total	2.199	11			

a. R Squared = .999 (Adjusted R Squared = .999)

Appendix-IV: Phytate and phytate mineral molar ratio of three sweet potato varieties

4.1. Phytate content of three sweet potato varieties

Tests of Between-Subjects Effects

Dependent Variable: phytate

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	4470.362(a)	5	894.072	254842.488	.000
Intercept	85151.477	1	85151.477	24271204.810	.000
Processing	2974.545	1	2974.545	847851.423	.000
Variety	1137.870	2	568.935	162166.682	.000
processing * variety	357.947	2	178.974	51013.827	.000
Error	.021	6	.004		
Total	89621.860	12			
Corrected Total	4470.383	11			

a. R Squared = 1.000 (Adjusted R Squared = 1.000)

4.2. Phytate: Calcium molar ratio of three sweet potato varieties

Tests of Between-Subjects Effects

Dependent Variable: Phytate: Calcium molar ratio

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1.323(a)	5	.265	15484.781	.000
Intercept	3.518	1	3.518	205907.361	.000
Variety	1.281	2	.640	37478.990	.000
Processing	.017	1	.017	1018.776	.000
Variety * Processing	.025	2	.012	723.576	.000
Error	.000	6	1.71E-005		
Total	4.840	12			
Corrected Total	1.323	11			

a. R Squared = 1.000 (Adjusted R Squared = 1.000)

4.3. Phytate: Iron molar ratio of three sweet potato varieties

Tests of Between-Subjects Effects

Dependent Variable: Phytate: Iron molar ratio

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	.201(a)	5	.040	172.029	.000
Intercept	4.687	1	4.687	20089.286	.000
Variety	.176	2	.088	376.821	.000
Processing	.007	1	.007	28.000	.002
Variety * Processing	.018	2	.009	39.250	.000
Error	.001	6	.000		
Total	4.890	12			
Corrected Total	.202	11			

a. R Squared = .993 (Adjusted R Squared = .987)

4.4. Phytate: Zinc molar ratio of three sweet potato varieties

Tests of Between-Subjects Effects

Dependent Variable: Phytate: Zinc molar ratio

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	62.788(a)	5	12.558	138.834	.000
Intercept	778.919	1	778.919	8611.592	.000
Variety	53.848	2	26.924	297.665	.000
Process	7.776	1	7.776	85.973	.000
Variety * Process	1.164	2	.582	6.433	.032
Error	.543	6	.090		
Total	842.249	12			
Corrected Total	63.330	11			

a. R Squared = .991 (Adjusted R Squared = .984)

4.5. [Phytate x Calcium]: Zinc molar ratio of three sweet potato varieties

Tests of Between-Subjects Effects

Dependent Variable: [Phytate x Calcium]: Zinc molar ratio

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	.016(a)	5	.003	127.126	.000
Intercept	.018	1	.018	718.355	.000
Variety	.016	2	.008	315.698	.000
Process	1.87E-005	1	1.87E-005	.748	.420
Variety * Process	8.75E-005	2	4.37E-005	1.744	.253
Error	.000	6	2.51E-005		
Total	.034	12			
Corrected Total	.016	11			

a. R Squared = .991 (Adjusted R Squared = .983)

Declaration

I certify that this thesis is my original work and has not been accepted for a degree in any other University and all sources of materials used for the thesis have been duly acknowledged.

Name: Endrias Dako

Signature: _____

Place: Addis Ababa University

Date of submission: 04-June 2012

The thesis has been submitted with my approval as supervisors

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Gulelat Desse (PhD, Associate professor)

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