34

Addis Ababa University

College of Natural Sciences

Centre for Food Science and Nutrition

Comparative Study on the Proximate Composition, Mineral Content, Antinutritional Factors and Sensory Acceptability of Raw and Boiled Three Yam Species Grown in Gamo Gofa Zone, Southern Ethiopia.

By

Fasika Tantu Saba

Advisors: Mr. Kelbessa Urga (Assoc. Prof.)

Professor Yalemtsehay Mekonnen

A Thesis Submitted to the School of Graduate Studies of Addis Ababa University in Partial Fulfillment of the Requirement for the Degree of Master of Science in Food Science and Nutrition

June, 2015

Addis Ababa, Ethiopia

Comparative Study on the Proximate Composition, Mineral Content, Antinutritional Factors and Sensory Acceptability of Raw and Boiled Three Yam Species Grown in Gamo Gofa Zone, Southern Ethiopia.

MSc. Thesis

By

Fasika Tantu Saba

Advisors: Mr. Kelbessa Urga (Assoc. Prof.)

Prof. Yalemtsehay Mekonnen

A Thesis Submitted to the School of Graduate Studies of Addis Ababa University in Partial Fulfillment of the Requirement for the Degree of Masters of Science in Food Science and Nutrition

June, 2015

Addis Ababa, Ethiopia

Acknowledgement

First and above all, I would like to unreservedly thank my advisors Prof. Yalemtsehay Mekonnen and Mr. Kelbessa Urga for their supervision and encouragement from the beginning until thesis defense. I do not remember the day they did not asked me about the progress of my research. They were always stood by my side even by giving me incentives that covered some part of my research budget. I have no words to express my respect and to say thank you for all their support and extraordinary comments which seasoned my thesis.

I would also like to express my sincere gratitude to the laboratory technicians of the Centre for Food Science and Nutrition at Addis Ababa University. Without their assistance this work wouldn't have been completed on time. I never forgot their kindness, respect, sincere approach, keenness to offer help and their hard work character as well. Special thanks should also go to Dr. Ashagrie Zewdu, Dr. Kaleab Baye, Mr. Tilahun Bekele, and Mr. Aynadis Tamene for they informally advised me when I was in need of it and when my advisors were not around. Prof. Sebsebe Demissew and Mr. Melaku Wondafrash also helped me in identifying the yam species in the Addis Ababa University National Herbarium and hence, I would like to extend particular appreciation to them.

My parents are always behind my success and with no overstatement are the best gifts for me from cheerful God. They helped me financially and morally by encouraging me when I despair and they enabled me accomplish my studies. I have come across many important and influential people in my life career, but I did not compare anyone with my friend Mr. Belay Binitu. He has invaluable moral support and comments during my entire study time at Addis Ababa University. He helped me a lot and I have nothing to give him in return than saying God bless him forever. Finally, I would like to thank Kucha district for offering me the chance to pursue my second degree in the esteemed program and all my friends who in one or in another way helped and/or encouraged me.

Table of Contents

List of Tables

List of Figures

List of Abbreviations

AAS-Atomic Absorption Spectroscopy

AAU-Addis Ababa University

ANOVA-Analysis of Variance

AOAC- Association of Official Analytical Chemists

IITA- International Institute of Tropical Agriculture

FAO- Food and Agricultural Organization

MT-Metric Tone

WHO-World Health Organization

PPM-Parts per Million

SPSS-Statistical Product and Service solution

LSD- List Significance Difference

Abstract

A comparative study on the nutritional value, mineral content, antinutritional factors and sensory acceptability of yam species (Dioscorea spp.) grown in Kucha district Gamo Gofa Zone, SNNPR were carried out. Three species of yam, namely D. cayenensis (hatiye), D. praehensilis (wadala) and D. bulbifera (bunde-buchi) were analyzed for their moisture, crude protein, crude fat, fiber, total ash, carbohydrate, gross energy, minerals (K, Ca, Na, Fe and Zn) as well as antinutritional factors, namely phytate, tannin, and oxalate. Raw Wadala contained significantly high amount of moisture in both raw (74.20%) and boiled (77.64%) tuber forms and also the highest protein (10.13g/100g), ash (3.07g/100g) and carbohydrate (86g/100g) contents were obtained for raw wadala. Bunde-buchi in its boiled form contained higher fat (1.0g/100g) and fiber (4.20g/100g) contents than other species. The highest calorific value was recorded for raw hatiye (385.42 Kcal) and was followed by raw wadala tubers (385.33 Kcal). Raw tubers of wadala had significantly high content of potassium (1029.62mg/100g) and Zinc (1.70mg/100g). Raw hatiye was relatively a good source of sodium (32.88mg/100g) and iron (2.02mg/100g). On the other hand, boiled tubers of bunde-buchi (81.95mg/100g) contained high amount of calcium than hatiye (55.04mg/100g). Generally, the anti-nutrients contents of the yam species were very low (<0.5mg/100g for phytate, <1.7mg/100g for oxalate, and <3.5mg/100g for tannin) and were reduced during boiling. Bunde-buchi had high level of oxalate (1.06mg/100g) and tannin (3.49mg/100g) whereas hatiye (0.44mg/100g) was high in phytate. In this study, boiling resulted in significant decrease in protein (by up to 20.78%), ash (by up to 39.4%), and gross energy values (by up to 1.08%). In contrast, boiling significantly increased the fat (by up to 26.8%) and fiber (by up to 164.4%) content of the three yam species. However, boiling didn't significantly reduce the anti-nutrients content of the three species. When compared with other root and tuber crops such as taro, cassava, and anchote, yam tubers had better nutrient content, but low antinutritional factors. The sensory analysis of the yam tubers indicated that hatiye was the most preferred species in most of the sensory attributes. In conclusion, the good nutrient content and low anti-nutrient content of the three yam tubers might make them potential food for the rural people in the country.

Key words: *Yam, Hatiye, wadala, bunde-buchi, and antinutrients*

1. Introduction

1.1. Background of the study

The nutritional health and well-being of humans are majorly dependent on foods of plant origin. Plants are critical components of the dietary food chain in that they provide almost all essential mineral and organic nutrients to humans (Grusak and Penna, 1999). They are also the most important source of food for human beings mainly due to their availability and low cost compared to consumption of animal-source foods which are often unavailable because of economic and /or religious concerns (Rosalind *et al.*, 2006). Among plant sources, root and tuber crops including cassava, sweet potato, taro and yam are consumed as staple foods especially in the less developed countries and raw materials for small-scale industries (Ravi *et al.*, 1996).

The term root and tuber refers to any growing plants that stores edible material in subterranean root, corm and tuber. Such crops constitute an important source of income in rural areas and have multiple uses as regular food crops and cash crops. Apart from providing basic food security and a source of income and diversity in diet, root and tuber crops also serve as source of proteins, essential vitamins, and minerals particularly for poor. Therefore, in developing countries, many farmers and food insecured peoples are highly dependent on root and tuber crops, as supplementary, if not principal, sources of food, nutrition, and cash income (Scott *et al* ., 2000).

Root crops are the primary staple foods of the west in Africa, with yam being the most prized crop. Although the New World crops of cassava and sweet potato have overtaken yam in range and volume, yam remains the dominant crop in the regions where they are best adapted. Where they have become subdominant, their cultural significance exceeds their dietary contribution (O'Sullivan, 2010).

Root and tuber crops are widely cultivated in southern Ethiopia, and support a considerable portion of the country's population as sources of food. Among these are potato (*Solanum tuberosum* L.), sweet potato (*Ipomoea batatas* L.), enset (*Ensete ventricosum*), godere (*Colacasia esculanta* L.), yam (*Dioscorea species*), and anchote (*Coccinia abyssinica Lam*) Enset, anchote, and some yam species such as *Dioscorea abyssinica* are believed to originate in Ethiopia (Addis, 2005).

Yam (*Dioscorea* spp.) is an annual or perennial tuber-bearing and climbing plant with over 600 species out of which six are economically important in terms of food and medicine (IITA, 2009). They are crops of major economic and cultural importance in sub-Saharan Africa that account for about 97% of the world production. They are mainly produced in West and Central African countries like Nigeria, Ivory Coast, Ghana and Benin (IITA, 2009). These countries are not only known for their production but also for their high per capita consumption which ranges from 258 Kcal to 364 Kcal.

Yam is widely grown in many parts of Ethiopia and plays a vital role in local subsistence. It is used as a staple and co-staple food in Southern Nations National and Peoples Regional State of Ethiopia. A number of *Dioscorea* spp. are grown in the country (particularly in Wolayita and Gamo-Gofa Zones) in mixed cropping systems together with cereals, and other root and tuber crops (Tamiru *et al.* 2008). About 23 indigenous yam types belonging to at least four *Dioscorea* species were reported in Sheko, Southeast Ethiopia (Hildebrand *et al.,* 2002). Mie´ge and Demissew (1997) described eleven Dioscorea species, both wild and cultivated which are found in the country. According to Tamiru *et al.* (2008) around 37 yam landraces are found in Wolayita and Gamo-Gofa Zones of Southern Ethiopia. The report indicated that of these, two landraces; *bola-boye* and *bunde-buchi* belong to a species of aerial yam (*D. bulbifera L.*) with the remaining specimens being unidentified. However, some of the landraces were believed to belong to *D. cayenensis* species complex. These indicate that yam species are widely distributed in Ethiopia, and are crop with potential for increased consumer demand. During a preliminary survey, three yam species locally called *hatiye*, *wadala* and *bunde-buchi* were brought to Addis Ababa University Herbarium and identified as *D. cayenensis*, *D. praehensilis* and *D. bulbifera,* respectively. As described by Tamiru *et al.* (2008), these three species were considered to be widespread in Gamo Gofa Zone, especially in Kucha district.

The yam tubers are good source of energy mainly from their carbohydrate (in the form of starch) contents though they are low in fat and protein. Nutrient content varies with species, age, geographic locality, storage conditions and cooking procedures. Root and tuber crops like yam are not easily digested in their natural state and should be boiled before they are consumed. Boiling improves their digestibility, promotes palatability, improves their keeping quality reduce the effect of anti-nutritional factors thereby making the roots safer to eat. However, cooking may affect the nutritional composition in food. The objective of this study is to evaluate the nutritional composition, mineral content, anti-nutritional factors and sensory evaluation of three *Dioscorea* species.

1.2. Statement of the problem

Many of the developing world's poorest farmers and food insecure people depends on root and tuber crops like yam as a traditional food source. Yam is an easily growing crop and has promising importance in areas where it grows as stapled food (FAO, 2009). In southern Ethiopia, yam supports a considerable proportion of the population as source of food. Yam is reported to be good source of dietary nutrients like carbohydrates, vitamins (e.g. vitamin C) and essential minerals (such as K, Ca, Na Mg, Fe and Zn) (Shanthakumari *et al.*, 2008; Maneenoon *et al.*, 2008; Arinathan *et al.,* 2009, Polycarp *et al.*, 2012). Many different forms and cultivars of the edible yam species are available in different areas and it is likely that these differ in composition and nutritional value (Bhandari *et al.*, 2003). For instance, research done on the minerals content of *D. abyssinica* indicated that the concentration of the minerals significantly varied with location of these species. The same report also showed that this species was considered to be a better source of K, Ca, Na, Fe and Zn to human compared to the common cereal flours (barely, wheat and red teff) as well as tuber food products like potato, cassava and enset (Aregahegn *et al.,* 2013). Another report on seven yam species in Ghana also revealed that significant differences exist among the species in chemical composition (Polycarp *et al.*, 2012). Study on the nutritional and antinutritional constituents of wild yam species in India reported that they are good source of protein, lipid, crude fiber, starch, vitamins and minerals (Shajeela, *et al.*, 2011).

Numerous reports in Africa and elsewhere on yam species indicated the presence of antinutritional factors such as oxalic acid and phytic acid which are capable of exerting inhibitory effect on the bioavailability and subsequent absorption of minerals (Shajeela *et al.*, 2011; Udensi *et al.*, 2010). Ezeocha and Ojimelukwe (2012), Shanthakumari *et al.* (2008) and Lawal *et al.* (2012) reported the presence of phytate and oxalic acid in significant amounts although they were affected by the preparation methods. A research conducted by Ayele (2009) on the effect of boiling temperature on the mineral content and antinutritional factors of yam and taro also indicated the reduction of the antinutrients with increased boiling temperature. The same report suggested that the tubers should be properly processed before consumption to eliminate the toxic effects and thereby to enhance the bioavailability of the minerals. There are several yam species which are commonly cultivated and consumed in Ethiopia. To date, there are only two researches which are conducted mainly focusing on mineral content *Dioscorea abyssinica* one of the species of *Dioscorea* (Aregahegn *et al.,* 2013) and mineral and antinutritional factors of unknown yam species (Ayele, 2006). Studies of nutritional values of yam is of considerable significance since it may help to identify forgotten food resources; however, comparative studies on yam nutrient composition, mineral content, antinutritional factors and consumer acceptability have not been given sufficient attention by the scientific community in Ethiopia. Thus, the aim of the present study is to compare the proximate composition, mineral content, antinutritional factors and to evaluate consumer acceptability of cultivated yam species grown in Gamo Gofa Zone, southern Ethiopia.

1.3. Significance of the Study

As yam is used as staple food in Southern Nations Nationalities and Peoples Region in particular, the findings of this research will enable people who consume yams to be aware of their nutritional values and will help them make informed choices among the three species. The result of the antinutritional factors will also suggest the preparation methods that result in improved nutrition and lower quantities of antinutritional factors of yam food. Determining and understanding the chemical composition and antinutritional factors of the underutilized yam tubers is vital to suggest possible ways and means to remove the antinutritional or toxic substances and make the edible tubers as safe food sources for mass consumption. The results will also be used by the University students, researchers and other stakeholders for further studies about yam species.

1.4. Objective

1.4.1. General objective

The general objective of this study is to compare the nutritional, antinutritional factors and sensory acceptability of three yam species grown in Gamo Gofa Zone, Ethiopia.

1.4.2. Specific objectives

The specific objectives of this study are:

- To compare the total carbohydrate, crude protein, crude fat, crude fiber, total energy and total ash content of yam species grown in Kucha district, Ethiopia.
- To compare the mineral content and antinutritional factors of yam species grown in Kucha district, Ethiopia.
- To evaluate the sensory acceptability of yam species grown in Kucha district, Ethiopia.
- To determine the effect of boiling on nutritional and antinutritional composition of three yam species grown in Kucha district, Ethiopia.

2 . Literature Review

2.1. Overview and origin of yam

Yam (*Dioscorea spp.)* is monocotyledonous angiosperm which belongs to the genus *Dioscorea* of the *Dioscoreaceae* family. They comprise several species of different origins; East Asia, West Africa, East Africa, Brazil and Guyana and today are grown widely throughout the tropics. Yams are considered to be among the most primitive of the angiosperms and contain over 600 species, of which only about ten are considered as edible, while a number of others are harvested from the wild in times of food scarcity (Bhandari *et al.* 2003).

Ethiopia is believed to be the centre of origin and biodiversity for some yam species like *Dioscorea abyssinica.* About 23 yam types belonging to at least four Dioscorea species were reported in Sheko, southeast Ethiopia (Hildebrand *et al.*, 2002; Tamiru *et a*l., 2008). Tamiru *et al.* (2008) reported that about 37 landraces of yam species in Gamo Gofa Zone, Southern region Ethiopia. The same report indicated the presence of *Dioscorea bulbifera* and *Dioscorea rotundata/cayenensis* complexes .These indicate that yam is widely distributed in Ethiopia and can become potential subsistence crop for farmers. As the crop is adapted to dry and rainy season, it is usually planted in October and harvested from the early maturing land races fill a seasonal gap in food supply during the months of May and June in the south, west and the south-west highlands of Ethiopia. In Ethiopia yam is commonly known by its vernacular names *Boyna* and *Ye hareg Boye.*

2.2. Edible yam species

Yam tubers are consumed as source of utilizable carbohydrate by millions of people in the tropical and subtropical regions and in some European countries (Asemota and Osagie, 1993). Yam tubers are classified as either edible or non-edible, where non-edible cultivars are used primarily for their medicinal properties (Komesaroff *et al.,* 2001). Although there are hundreds of yam species worldwide, only about 10 species are edible. Yams are such a diverse species that there exist various cultivars of the same species which have different tuber shape and flesh colour (Behera *et al.*, 2009). The various species can be distinguished based on tuber shape, tuber-skin colour and structure, tuber flesh colour and tuber-flesh texture; or on the colour of sprout and shoot tips, quantity and distribution of spines and bloom on the stem, presence of aerial bulbils, direction of vine twisting, and leaf shape, size, and colour (Onwueme, 1978).

2.2.1. *Dioscorea rotundata* and *Dioscorea cayenensis*

Dioscorea rotundata (white yam) is the most economically important yam species which is originated and commonly cultivated in West Africa. The tuber is smooth and cylindrical in shape with white flesh colour. *Dioscorea cayenensis* (also called yellow yam) is also native to West Africa and are in many respects similar to white yam. The distinction between these species is unclear, and some researchers prefer to refer to them as *Dioscorea cayenensis-rotundata* species complex (Hahn, 1995), while others still argue that they should be recognized as separate taxa (Mignouna *et al.*, 2005).

2.2.2. *Dioscorea alata*

Dioscorea alata (water yam or winged yam or purple yam) is a climbing plant with smooth leaves and twining stem which coil readily around a stake and originated from South East Asia, but recent genetic studies have identified Melanesia as its centre of origin, and this region remains its centre of diversity. It is second only to white yam in popularity and is the most widespread species (Lebot, 1999). *Dioscorea alata* tubers have variable shape with the majority being cylindrical. Tuber flesh is purple in colour and is watery in texture. It is an important food in Africa, the Caribbean, and especially Melanesia where it has considerable social and cultural importance (Lebot *et al.*, 2005). In addition to social and cultural importance *D. alata* is a crop with potential for increased consumer demand due to its low sugar content necessary for diabetic patients (Udensi *et al.*, 2010).

2.2.3. *Dioscorea bulbifera*

Dioscorea bulbifera (air potato) is found in both Africa and Asia, with slight differences between those found in each place. It is a large vine, 6 meters or more in length it produce tubers however the bulbils grow at the base of its leaves are the most important food product. They are about the size of potatoes (hence the name air potato) weighing from 0.5 to2 kg (Schulz.1993). It is not grown much commercially since the flavour of other yams is preferred by most people and distinguished from all other yam species by having specialized aerial bulbils on the base of petioles and the bulbelates of *D. bulbifera* have very high dry matter content; the flesh being very firm after cooking (Kochar,1998).

2.2.4. *Dioscorea dumetorum*

Dioscorea dumetorum the bitter yam originated in tropical Africa and occurs in both wild and cultivated forms but its cultivation is still restricted in West and Central Africa. It is a popular plant in parts of West Africa; one reason is that their cultivation requires less labour than other yams. However, it is underutilized because most wild forms of the species are toxic in nature (Kay, 1997). *Dioscorea dumetorum* is characterized by bitter flavour of its tuber and tuber flesh hardens if not cooked shortly after harvest (Mignouna et al., 2004).

2.2.5. *Dioscorea trifida*

Dioscorea trifida, cush yam is native to the Guyana region of South America and is the most important cultivated New World yam. Since they originated in tropical rain forest conditions their growth cycle is less related to seasonal changes than other yams. Because of their relative ease of cultivation and their good flavour, they are considered to have a great potential for increased production (Kay, 1997).

2.2.6. *Dioscorea esculenta*

Dioscorea esculenta the lesser yam was one of the first yam species cultivated. It is native to South East Asia and is the third most commonly cultivated species there, although it is cultivated very little in other parts of the world. Its vines seldom reach more than 3 meters in length and the tubers are fairly small in most varieties. The tubers are eaten baked, boiled, or fried much like potatoes. Because of the small size of the tubers, mechanical cultivation is possible which along with its easy preparation and good flavour could help the lesser yam to become more popular in the future (Kay,1997).

2.3. Agronomic requirements of yam

Yam is grown and cultivated for its energy-rich tuber. It is adaptable to fairly fertile soils and is suitable for intercropping which is cropping yam in a well designed row with others crops such as maize (*Zea mays* L.), sweet potato (*Ipomoea batatas* (L) *Lam.*), cabbage (*Brassica spp.*), beans (*Phaseolus spp.*) and, to a lesser extent, of coffee (*coffea Arabica* L.). A well-drained, rich, loamy soil however is the most favourable. It is also requires a warm, humid climate; however, the crop possesses considerable drought resistance and gives more calories per unit of land area than most crops and matures within seven months (Tamiru *et al*., 2008).

Yam tubers are highly variable in appearance both between and within species, beside variable in appearance all yams share a common growth habit of thin, twining vines and a shallow, widely radiating root system, both of which die and are renewed each year. All economically important species are tuberous, producing one or more underground tubers, which are starch storage organs and derived from, stem tissue. The tubers provide a means of vegetative propagation from one season to the next. In most cases the tubers are annual they shrivel at the start of the new growing season and are replaced by new tubers. However, some genotypes of several species produce perennial tubers, which may continue to grow over several years. Many species produce aerial tubers, or bulbils, as a means of vegetative dispersal (O'Sullivan, 2010).

2.4. Production of yam

Yams are found in a wide variety of production systems and its production is relatively expensive compared with other root and tuber crops as it requires intensive cultivation, particularly with respect to labour and planting material. In the past, yams are traditionally propagated by whole tubers or relatively large tuber pieces. But currently, small yam tuber pieces which are obtained from the previous season's harvest are used as planting material (O'Sullivan, 2010). Yam is an important food crop especially in the yam zone of the West Africa. It is the second most important tuber crop in Africa with production reaching just under one third the level of cassava. Yam is grown on 5 million hectares in about 47 countries of the world. West Africa accounts for 90-95% of world yam production with Nigeria as the leading world producer (FAO, 2005; IITA, 2009). Nigeria alone accounts for about 70 percent of world production. In 2004, global yam production was about 47 million metric tons (MT) with 96% of this coming from Africa. In 2005, 2.83 million hectares of land (which is 97% of the global area under yam cultivation) was covered by yam in Sub-Saharan Africa which accounts for 70% of global production and the world production was increased to 48.7 million hectares (IITA, 2009).

Other countries where a significant production of yams occurs are Brazil, Venezuela, Papau New Guinea, China and Philippines. The total annual production of yam in Ethiopia was estimated at about 277, 000 metric tons from an area of about 68, 000 hectare, corresponding to a yield of about four tons per hectare (FAO, 1997).

2.5. Importance of Yam

Roots and tuber crops especially yam occupies remarkable position in the food security of the developing world due to their high caloric value and carbohydrate content. Some of them are already cultivated but others are grown wild as neglected group of economic plants (Vimala and Nambisnia, 2005).Yam is a preferred food and a food security in East and West Africa where 95% of the world production occurs.

Apart from being used for family food, yams are also an indispensable cash crop for farmers. Studies proved that yam is a highly profitable crop in the yam zone constituting 32% of farmers' gross income derived from arable crops (Lagegmann, 1977). In some markets in Southern Ethiopia, the price for yam (especially *D. cayenensis*) is far higher than other root crops such as sweet potato and cassava. Yam also plays a significant role in African socio-cultural traditions. Nigeria, the world largest yam producer, considers it to be a totem for masculinity and traditional ceremonies still accompany yam production and utilization indicating the high status given to the plant (Abraham, 1998). In southern Ethiopia, mainly in some districts of Gamo-Gofa zone, it is common that a food called *fichata* is prepared from yam tuber, fermented milk, and, butter and consumed by almost all households at the eve of Meskel holiday.

Yam also plays a significant role in traditional medicine to treat various ailments. *D. dumentorum* for example is used in African traditional medicine for the treatment of diabetes (Bahera et al, 2009). Several species of yams have medical properties and the tuber is said to contain some pharmacologically active substances including dioscorine, saponin and sapognin (Bahera et al, 2009). *D. bulbifera* is used in china to treat cancers, stop bleeding and reduce inflammation. Dietary diosenin has been shown to decrease plasma cholesterol levels in numerous animal models (Raemaekrs, 2001). Yam contains different types of organic acid, phenolic compounds and anti-oxidant chemical having varieties of health effects. Therefore, consumption of fresh yam tubers may prevent against human diseases in which free radicals are involved such as cancer and cardiovascular diseases (Bhandari and Kwabata, 2004).

2.6. Nutrient Composition of yams

Yam is considered to be an excellent source of carbohydrate, energy, vitamins, minerals and protein (Wanasundera and Ravindran 1994). The chemical composition of yam is characterized by a high moisture content and dry mater. Yam species differ in terms of dry matter content, starch quality, texture and flavor which affect their suitability for different and cooking procedure (Hariprakash and Nambisan, 1996). It contains approximately four times as much protein as cassava, and is the only major root crop that exceeds rice in protein content in proportion to digestible energy (Bradbury and Holloway (1988). Reports from a number of studies have shown that yam tubers contain high water content up to 92% (Shajeela *et al.*, 2011; Adepoju, 2012). The moisture content of yam species ranges from 58% for *D. rotundata* to 79% for *D. Dumetorum* (Polycarp *et al.*, 2012)

Several researches in Africa and elsewhere revealed that a yam tuber has good protein content compared to other root and tuber crops such as cassava and taro. Adepoju (2012) reported that the protein content of raw white yam (*D rotundata*) was 2.3% in dry matter basis and was significantly reduced with boiling. However, the crude protein content was significantly improved when the tubers were roasted and fried. Other finding has shown that raw *D. alata* and *D. Dumetorum* contain a crude protein content of 10.27% and 11.41% on dry matter basis, respectively (Ezeocha and Ojimelukwe 2012;Ezeocha *et al.*,2012). The two reports also indicated that the crude protein content was significantly reduced by the increased boiling temperatures. Research done on seven yam species (*Dioscorea rotundata, D. cayenensis, D. alata, D. esculenta, D. bulbifera, D. dumentorum* and *D. praehensilis)* in Ghana revealed that the protein contents ranges from 4.03 to 6.52% on dry matter basis with *D. dumentorum* being the highest (Polycarp *et al.*, 2012). According to this report, the crude protein content for raw *D. cayenensis*, *D. praehensilis* and *D. bulbifera* were 5.78, 5.38 and 4.58, respectively.

Yams are the cheapest sources of calorific energy in the form of carbohydrates (mainly dietary starch) in developing countries (Ugwu, 2009; Coursey, 1973).Yam species such as *D. alata* are highly preferred due to their low sugar content necessary for diabetic patients (Udensi, 2010). Research conducted on seven yam species (*D. rotundata. bulbifera, D. cayenensis, D. praehensilis, D. dumetorum, D. alata* and *D. esculenta*) showed that yams contain high carbohydrate content, ranging from 77.5 to 87.3% with *D. rotundata* being the highest (85.51-

87.31%) followed by *D. bulbifera* (81.76-82.52%) and *D. praehensilis* (82.52%) (Polycarp *et al.*, 2012). According to Olajumoke *et al.*, (2012), the carbohydrate content for raw and boiled *D. rotundata* tubers was 69.5% and 68.57% on dry matter basis, respectively. However, several studies reported that yam tubers contain relatively low dietary fibre. The fibre content of *D. cayenensis* ranged from 1.91-2.44%, *D. bulbifera* contained a fibre content of 2.03-2.35% and *D. praehensilis* was reported to have crude fiber content of 1.41% on dry matter basis (Polycarp *et al.*, 2012).

Yam species have low fat content often < 1% on dry matter basis. For instance, the crude fat content of *D. dumetorum* is reported vary from 0.54% in tubers boiled for 90 minutes to 0.71% for raw tubers (Ezeocha *et al.,* 2012);*D. Rotundata* is reported to have 0.8% fat and the lipid content of *D. alata* ranges from 0.09%in tubers boiled for 90 minutes to 1.15% for raw tubers (Ezeocha and Ojimelukwe, 2012). Polycarp *et al.* (*2012*), reported that the fat contents of *D. rotundata*, *D. bulbifera*, *D. cayenensis*, *D. praehensilis*, *D. dumetorum*, *D. alata* and *D. esculenta* were 0.46%, 0.55%, 0.53%, 0.48%, 0.61%, 0.81% and 0.76%, respectively. However, Shajeela *et al.* (2011) reported remarkable amount of fat for raw *D. alata* and *D. bulbifera* which was 5.28 and 6.14% on dry mater basis, respectively.

Several studies investigated that potassium is the most abundant dietary mineral in yam tubers. The potassium content of raw yam tubers ranges from 475mg/100g (for *D. rotundata*) to 1475 mg/100g (for *D. bulbifera*) (Polycarp et al., 2012). Shajeela *et al.*, (2011) also reported a potassium content of about 786.3mg/100g and 1554mg/100g, for *D. alata* and *D. bulbifera*, respectively. Research conducted by Adepoju, (2012), showed that the potassium content of boiled *D. alata* tubers was 390mg/100g which was significantly lower than the figure reported for raw *D. rotundata* tubers. The potassium content of D. abyssinica ranges from 847mg/100g to 1391mg/100g (Aregahegn *et al.*, 2013). Yam are relatively good source of Ca. Polycarp et al. (2012) reported that the calcium contents of yam species ranged from 6.5mg/100g to 103.25 mg/100g with *D. rotundata* and *D.bulbifera* being the highest and *D. alata* being the lowest in Ca levels. But Shajeela *et al* (2011) reported that *D. alata* and *D. bulbifera* had high calcium content, in that order, 448.36 and 338.15mg/100g. On the other hand, the calcium content of *D. abyssinica* ranged from 17.2 to 44.8 mg/100g (Aregahegn *et al.*, 2013). On the other hand, yams are reported to contain high levels of dietary sodium, ranging from 62.5 to 102.5 mg/100g.*D.*

cayenensis is reported to have 70 mg/100g, *D. bulbifera* contains 102.5 mg/100g and *D. praehensilis* is reported to have 80 mg/100g sodium (Polycarp *et al.*, 2012).

Polycarp et al. (2012) reported that the iron contents of yam species ranged from 1.50 mg/100g to 9.00 mg/100g with *D. praehensilis* being the highest and *D. alata* being the lowest in iron levels. But Shajeela *et al* (2011) reported that very higher iron content compared with Polycarp et al. (2012) that is ranged from 11.48 mg/100g (*D. esculenta*), to 66.32 mg/100g (*D. pentapylla*). On the other hand, the iron content of *D. abyssinica* ranged from 2.8 to 14.4 mg/100g (Aregahegn *et al.*, 2013). Zinc is one of dietary mineral in yam tubers. The zinc content of raw yam tubers ranges from 5.40 mg/100g (for D. praehensilis) to 7.80 mg/100g (for D. esculenta) (Polycarp et al., 2012). Shajeela *et al.*, (2011) also reported zinc content 1.48 mg/100g (for bulbifera) to 6.66 mg/100g for (D. wallichi). Research conducted by (Aregahegn *et al.*, 2013), showed that the zinc content of D. abyssinica ranges from 1.2 mg/100g to 4.5 mg/100g.

2.8. Antinutritional Factors

With ever-increasing population pressure and depletion of natural resources it has become very important to diversify the present-day agriculture in order to meet various human needs (Janardhanan *et al*,. 2003). The world food crisis has been and will continue to be a major obstacle to humanity. The observed interest search for alternative/additional plant product food and feed ingredients like yam is paramount importance (Siddhuraju *et al.*, 2000). However, nature has endowed plants with the genetic capacity to synthesize substances that are toxic, and thus to ensure their survival against predators whether they be insects, fungi or animals including humans. The presence of such factors limits the wider food utilization of many tropical plants like yam. Humans have learnt which foods are safe to eat or how such foods can be treated in order to destroy their toxicity use and have developed suitable techniques for detoxifying the food before consumption. One of these toxic materials is anti-nutritional factors (Shanthakumari *et al.*, 2008). Antinutritional factors are chemical compounds synthesized in natural food that acts antagonistically towards one or multiple essential nutrients, reducing their bioavailability. These compounds form complexes with nutrients, reduce nutrient absorption and exert effects contrary to optimum nutrition (Thompson, 1993). Like most foods of plant origin, yam tubers are also known to contain different toxic substances or antinutritional factors such as oxalates, phytates, trypsin and amylase inhibitors, tannins, and cyanide that affect both human and animals when they are consumed, despite their high nutritional values. Earlier reports have also pointed out that a few yam species contain some toxic compounds and can impose serious health complications (Anthony, 2004). Consumption can result in gastro intestinal disturbances, vomiting and diarrhea especially when large amounts are ingested in to the human body. Therefore, it is advisable to process yams before consumption. Despite their possible detrimental effect, many of those considered being antinutritional factors including polyphenols and protease inhibitors are also known to have health benefits. Some of the health benefits include lowering blood glucose and hormonal responses, reduction of blood lipids and reduction of the risk of cancer (Thompson, 1993).

Phytate also known as inositol hexakisphosphate is the salt form of phytic acid, a phosphorus containing naturally occurring compound formed during maturation of plant seeds and grains that binds with minerals and inhibits mineral absorption due to the structure. Phytate has high density of negatively charged phosphate groups which form very stable complexes with mineral ions causing them less available for intestinal absorption (Walter *et al.*, 2002). Yam tubers contain some amount of phytate which ranges from 0.89mg/100g for *D. alata* to 4.16mg/100g for *D. cayenensis* (Polycarp *et al.*, 2012).

Tannins are generally a heterogeneous group of high molecular weight phenolic compounds (500 to over 3000 Daltons) with the capacity to form reversible and irreversible complexes mainly with proteins and various other organic compounds including polysaccharides, amino acids, nucleic acids, alkaloids and minerals (Redden *et al.*, 2005). Tannins are widely distributed in many plant species grown mainly in tropical or arid/semi-arid areas (Perevolotsky, 1994). The tannin content of yam tubers ranges from 4.40 mg/100g for *D. cayenensis* to 13.20 mg/100g for *D. alata*. Arinathan *et al.* (2009) reported high level of tannin (255 mg/100g) for underutilized Dioscorea tubers. Other root and tubers such as taro also contain significant amount of tannin (26.94-47.69 mg/100g) (Adane *et al.,* 2013). However, Shajeela et al. (2011) reported low level of tannins in *D. alata* (0.41 mg/100g) and *D. bulbifera* (1.48 mg/100g). Processing methods such as boiling, frying, and fermentation are known to reduce the tannin content of foods. According to Adane et al. (2013), fermentation and boiling resulted in 43.52% and 6.69% reduction of tannin content of taro root respectively. Udensi *et al.* (2010) also reported tannin content of 46 to 180 mg/100g for D. alata varieties.

Oxalic acid is one of the naturally occurring organic acids found in plans, animals and in humans. Oxalates such as calcium oxalate (salt forms of oxalic acid) have been found to be widely distributed in plants (Prakash, 1993). Oxalates can be found in relatively small amounts in many plants and are unevenly distributed within plant tissues. Plant leaves contain the highest level of oxalates followed by seeds and generally, plants contain higher concentration of oxalates than meats (Horrocks *et al.*, 2008). Earlier reports have pointed out that a few yam species contain toxic compounds such as oxalates which can result in serious health complications (Anthony, 2004). Unlike taro which contains high oxalate content as high as 243.06 mg/100g (Adane *et al.*, 2013), yams contain small amount of oxalate ranging from 0.2 to 0.63 mg/100g (Shajeela *et al.*, 2011). Several studies have shown that the oxalate content of foods changes as a result of processing. For example, boiling is reported to significantly reduce (up to 70%) the soluble oxalate content of vegetables and tuber crops especially when the cooking water is discarded (Adane *et al.*, 2013).

2.9. Traditional processing methods and utilization of yam in Ethiopia

Food processing refers to all the processes to which food is subjected after harvesting with the aim of improving its appearance, texture, palatability, nutritive value, shelf-life, ease of handling and preparation as well as for eliminating both disease-causing and spoilage microorganisms, toxins, and other undesirable constituents (Vanhonacker *et al* ., 2008). The method of processing root and tuber crops ranges from simple boiling to complex fermentation, roasting, frying, drying and grinding to make flour depending on the varieties, and type of product to be produced. These processing activities also extend the shelf life of perishable roots and tuber crops.

Like many other root and tuber crops, processing of yam tuber is an ancient practice. Traditionally, yam is prepared in several ways for immediate consumption. Yam tubers are consumed in forms of *chunks*, *flour*, *chips*, *fufu* and *slices*, which are obtained from any of the processes of boiling, frying, drying, fermentation, milling, pounding, roasting and steaming (Iwuoha, 2004). In most parts of Ethiopia, yam is eaten mostly boiled. In the study area, yam tuber is dug out of the ground, washed with water, bark peeled with knife and boiled in traditional pot locally known as 'otto' in Gamogna language for about one hour with the water then drained off. The boiled yam is consumed traditionally in a fashion similar to potato either alone or combined with appetizers such as 'datta', in local language, which is prepared from chili pepper, ginger, garlic, butter and salt.

In Gamo-Gofa Zone, yam is the most preferred food for privileged guests and very often traditional meals made of yam are served during the main traditional and religious festivals. In Gamo Gofa and Wolayita Zones boiled, yam tubers are smashed and mixed with butter and fermented milk to prepare the popular dish known as *fichata* or *hotorsa*. This is different from the utilization in most West African countries where the tuber is consumed boiled, mashed, fried, roasted, and baked. For this reason, yam fetches higher prices on local markets compared to the other roots and tubers such as cassava, sweet potato and taro. Therefore, yam is important not only for the household food security but also as source of income.

2.10. Sensory acceptability

Sensory evaluation has been defined as a scientific method used to evoke, measure, analyze, and interpret those responses to products as perceived through the senses of sight, smell, touch, taste, and hearing (Stone and Sidel, 1993). One of the main objectives of sensory evaluation is the measurement of sensory attributes and the quantification of the influence of these attributes on consumer acceptance (Meilgaard *et al.*, 1999). There are many types of sensory analysis methods, the most popular being difference tests, descriptive analysis and consumer acceptance testing and each testing method has different goals (Vaclavik and Christian, 2008). Difference or Discrimination test are one of sensory testing method which are designed to determine whether there is a difference between a products. Difference tests also can be used to see if the quality of a product changes overtime or to compare the shelf life of a particular product packaged in different packaging materials. Descriptive sensory analysis is defined as a sensory testing method by which the attributes of a food or product are identified and quantified, using human subjects who have been specifically trained for this purpose. The primary aim of all descriptive techniques is to generate quantitative data which describes the similarities and differences among a set of products (Stone and Sidel, 1993: Vaclavik and Christian, 2008). Affective, acceptance, or preference tests are used to determine whether a specific consumer group likes or prefers a particular product. This is necessary for the development and marketing of new products, as no laboratory test can tell whether the public will accept a new product or not. This testing is expensive and time-consuming (Vaclavik and Christian, 2008).

3. Materials and Methods

3.1. Description of Sampling Area

Samples were collected from Kucha district, Gamo Gofa Zone, Southern Nations, Nationalities and Peoples Region from farmers land. Kucha district is located at a distance of 450 Km from Addis Ababa to the South and is 176 Km far from the zone capital, Arba Minch. The area is located at an altitude range of 1100 to 2400 meters. The population of Kucha Woreda is estimated to be about 187,241. The area has receives an average annual rain fall of about 1600 mm. The highest and lowest rainfalls are recorded from June to September and from March to April, respectively. The average annual temperature is 22.5°C and the annual maximum and minimum temperatures are about 25°C and 20.1°C, respectively. The reason for selection of this site was based on the availability of the plant and its popularity in consumption.

Agriculture (crop cultivation and rearing of livestock) is the leading economic activity in the district. The food crops cultivated in the district are cereals (sorghum, barley, teff and maize), pulses (pea, beans, and, groundnut), fruits (banana, papaya, avocado mango, orange, and pumpkin), leafy vegetables (cabbage, moringa, lettuce, etc.), spices (pepper, chilies, and ginger), root and tuber crops, (cassava, taro, sweet potato, inset and yam). In addition, rearing of livestock such as large ruminants cattle, small ruminants such as sheep, got, and equine such as donkeys, hors are common (CSA, 2008).

3.2. Sample Collection

At the beginning of the study, voucher specimens were collected for each plant species and preliminary identification of the collected specimens were made in the field by Kucha Woreda agricultural office expert then the collected specimens were dried. The voucher plant specimens were brought to the Addis Ababa University National Herbarium for identification. The specimens were identified by a botanist at the National Herbarium of Addis Ababa University as *D. Cayenensis* (locally named as hatiya), *D. Praehensilis* (wadala) and *D. bulbifera* (bunde-buchi).

All necessary steps were followed by the expert during identification by using published flora volumes of the Ethiopia and Eritrea and by comparing with authentic herbarium specimens, and finally confirmed by taxonomist. All voucher specimens were deposited at the national Herbarium.

After identification, matured plants were purposively selected from farmer's land. About 10 kilograms of large, medium and small sized tubers per species were harvested. The tubers were divided into two portions. One portion of the tubers was used for consumer sensory evaluation and the second portion was packed in polyethylene bags, labeled, and kept in an icebox to be transported to the centre for food science and nutrition laboratory of Addis Ababa University.

Figure 1. Leaf and Tuber Parts of *hatiya* (*D. cayenensis*) (Photo taken by the researcher on 30/12/2015)

Figure 2. Leaf and Tuber Parts of *Wadala (D. praehensilis)* (Photo taken by the researcher on 30/12/2015)

Figure 3. Leaf and Tuber Parts of *bunde-buchi* (*D. bulbifera*) (Photo taken by the researcher on 30/12/2015)

3.3. Sample Preparation

Upon arrival, the tubers brought to laboratory were separately cleaned to remove surface foreign matters using distilled water and hand peeled carefully using stainless steel knives. The peeled tubers were divided into two portions. Then, about 500g of one of the portions was sliced in to pieces to be dried and made into flour. For this purpose, the slices were dried overnight in a hot air oven which is kept at 50°C, milled using an electric mill and sieved through a 0.425 mm mesh size. Finally, the flours were bagged in polythene bags which were properly labeled and stored in dry place. Moisture was quickly analyzed as soon as peeled tubers.

The second portion was used for preparation of boiled yam tubers. About 500g of peeled yam tubers were cooked for about 45 minutes after boiling in 1.5 litre of distilled water in a metal pot. By inserting fork into the tubers, the tubers were recognized wether cooked to edible or not. Then, the tubers were sliced in to approximately 1 mm thick by knife, spread on plastic plate, and allowed to dry in an oven maintained at 50°C for overnight. Finally, the boiled dried yam chips were milled to flour using a mill, sieved through a 0.425 mesh sieve, bagged in transparent polythene bags, labeled and stored in dry place for later analysis.

3.4. Sensory Acceptability Evaluation

For sensory analysis, one of the portions of the harvested tubers was boiled according to the flow chart described below. Panel consisting of 15 untrained consumers were selected on the basis of interest and availability out of this 11 (60%) were males and 6 (40%) were female participants and the consumers were between the ages of 18-35 years. The evaluation was conducted in Kucha Woreda Agricultural Office following standard procedures (Eddy *et al.*, 2007). The assessors were first given orientation to understand the sensory attributes and also to use these attributes to describe the boiled yam tubers. During the evaluation session, each panelist was provided with three coded samples of boiled yam and the sensory evaluation questionnaire as well. Sensory attribute assessed include colour, taste, aroma, texture and over all acceptability. Seven point hedonic scale with one representing extremely dislike and seven representing extremely like was used for evaluation. Panelists were also given the chance to comment on the samples. Water was supplied to the panelists in order to refresh their palates before tasting subsequent samples.

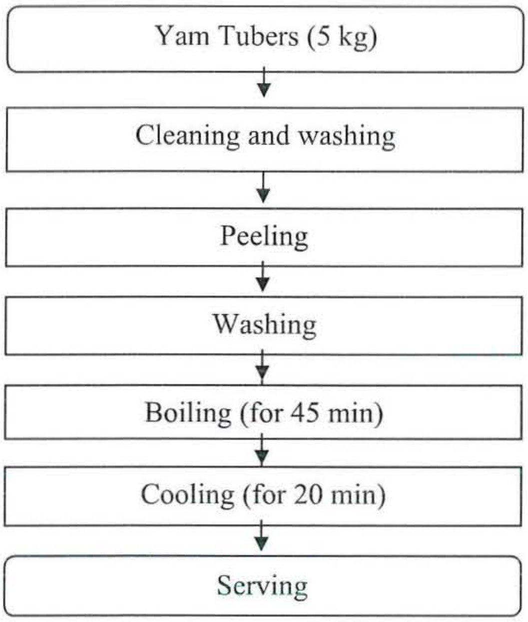


Figure 4. Flow chart for traditional processing of yam in Kucha district

3.5. Analysis of proximate composition

3.5.1. Moisture analysis

The moisture content of the raw and boiled samples was determined by hot air drying method according to the official method of 925.09 of AOAC (2000). Steel crucibles were dried in a drying oven at 105°C for 1 hour. The crucibles were taken out from the oven, cooled in a desiccator for 30 minutes and then their weight was measured (W_1). Five g of the sliced fresh and dried yam samples was weighed in the crucibles and dried in drying oven at 105°C for 3 hours. Then, the weight of the crucibles containing the sample was measured (W_2). After drying, the crucibles containing the dried sample were cooled in a desiccator to room temperature and weighed until constant weight was obtained (W_3). The moisture content of the tubers was calculated by using the following formula.

$$Moisture\ \% = \frac{W2 - W3}{W2 - W1} \times 100$$

Where, W1=Weight of the dish, W2=Weight of the dish and the samples before drying

W3=Weight of the dish and the sample after drying

3.5.2. Crude protein

Protein content was analyzed by the micro Kjeldahl method according to the official method 979.09 of the AOAC (2000). The general procedure included the following steps of digestion: 0.5 g of the dried raw and boiled yam samples was weighed in a cleaned Kjeldahl flasks and 6 mL of concentrated sulphuric acid was added for digestion. In a drop wise manner 3.5 mL of hydrogen peroxide was added and 3g of catalytic mixture of potassium sulphate and copper sulphate was also added and the reaction was left for 15 minutes. The mixture was digested in a digest stove initially at low temperature to prevent frothing and then at 370 °C for 4 hours until a clear digest was obtained. After digestion, it was cooled in the hood on the rack. Twenty five mL of distilled water was added to prevent precipitation of the sulphate. Twenty five mL of 35 %NaOH was added to neutralize sulphuric acid and thus, ensure complete release of ammonia. A 250 mL Erlenmeyer flask containing, twenty five mL of four % H_3BO_3, twenty five mL of distilled water and three drops of methyl red indicator was placed as receiver on the distillation unit. The distillation process continued until the volume of the distillate reached one hundred fifty mL or more. The distillation was continued for one to two minutes after the receiver flask is lowered such a way that the delivery tube is above the liquid surface. Then, the delivery tube was rinsed with distilled water and the washings were allowed to drain into the flask. Finally, the distillate was titrated with standardized 0.1 N HCl until the appearance of the first pink colour and the amount of HCl consumed was recorded. Moreover, reagent blank was run to subtract reagent nitrogen from the sample nitrogen. The amount of protein was calculated by using the following formula.

$$Crude\ protein\ (\%) = \frac{(V2 - V1) \times N \times 14.01 \times 6.25}{10 \times W}$$

Where,

V1= volume (ml) of hydrochloric acid solution required for the blank test,

V2= volume (ml) of hydrochloric acid solution required for the test sample,

N= normality of hydrochloric acid, W= Wight of the sample, 10 = factor relating mg /g

14.01= equivalent weight of nitrogen, 6.25= conversion factor for foods

3.5.3 Crude fat

The crude fat was extracted using Soxhlet apparatus according to AOAC (2000) official method 4.5.01. About 2 grams of the dried raw and boiled yam samples was weighed in thimble containing fat free cotton (W_1). The extraction cylinder was washed with distilled water and detergent and then dried. The cylinder was cooled in a desiccator for 30 minutes and weighed (W_2). Fifty mL of diethyl ether with boiling point of 34.6°C was added into the cylinder and the thimble was immersed into the cylinder containing diethyl ether for 2 hours. Fat extraction was done for extra 2 hours, while the temperature was set at 55°C. After that the cylinder containing the extracted fat was dried in drying oven to a constant weight at 70°C for 30 minutes. Finally, the cylinder containing the extract was cooled in a desiccator for 20 minutes and weighed (W_3). The amount of extractable fat was calculated by using the following formula.

$$Crude\ fat\ (\%) = \frac{W3 - W2}{W1}$$

Where,

W1= Weight of sample, W2= weight of cylinder, W3= weight of cylinder + fat,

W3-W2= weight of fat

3.5.4. Crude fibre

Crude fibre content of yam samples was determined according to the method 962.09 of the AOAC (2000). The analysis involved the steps of digestion, filtration, washing, drying, and combustion.

Digestion

About 1.5 grams of yam flour was weighed in a 600 mL beaker and 200 mL of 1.25% H_2SO_4 was added. The beaker was covered with a watch glass and the mixture was gently heated on a hot plate for 30 minutes while keeping the level constant with distilled water. Then, 20 mL of 28% KOH was added and the solution was boiled for additional 30 minutes while constantly stirring.

Washing and Filtration

The bottom of a sintered glass crucible was covered with 10 mm thick sand and the layer was moistened with a little distilled water. Next, the solution was poured from the beaker into sintered glass crucible and then burned on vacuum pump. Then, the beaker walls were rinsed several times with hot distilled water and the washings was transferred to the crucible and filtered. The residue in the crucible was washed with hot distilled water and filtered twice. After that the residue was washed with 1% H_2SO_4 and filtered and then washed with hot water and filtered. After that the residue was washed with 1% alkaline solution (NaOH) and filtered. The residue was also washed with 1% H_2SO_4 and filtered for the second time. Finally, the residue was washed with water-free acetone.

Drying and combustion

The crucible was dried in a drying oven for 2 hours at 130°C. The crucible was cooled in a desiccator for 30 minutes and its weight was recorded. Then, the crucible was transferred to a muffle furnace to be ashed at 550°C for 30 minutes. After 30 minutes, the crucible was cooled in a desiccator and weighed again. The crude fiber content of yam samples was calculated by using the following formula.

$$Crude\ fiber\ (\%) = \frac{(W1 - W2) \times 100}{W3}$$

Where, W_1 = crucible weight after drying, W_2 = Crucible weight after ashing, and

W_3 = Weight of sample

3.5.5. Total carbohydrate content

The total carbohydrate content of the raw and boiled yam samples was determined by difference method that is by subtracting the sum of the percentages of moisture, crude protein, crude fat, fibre, and ash content from 100%.

3.5.6. Gross energy

Gross energy was determined by calculation from fat, carbohydrate and protein contents using the Atwater's conversion factors; 16.7 kJ/g (4 kcal/g) for protein, 37.4 kJ/g (9 kcal/g) for fat and 16.7 kJ/g (4 kcal/g) for carbohydrates and expressed in calories (Guyot et al.,2007).

3.5.7. Total ash content

The ash content was determined according to the official method of 923.03 of the AOAC (2000). Clean porcelain crucible was dried at 105°C in hot air oven and in addition was ignited at 550°C for about 1 hours in a muffle furnace. Next, the crucible was cooled in a desiccator for about 30 minutes to room temperature and weighed until constant weight using analytical balance (W_1). About 2.5 g of dried yam sample was weighed into the cleaned crucible (W_2). Then, it was charred on a hot plate at low temperature to avoid spattering until the smoke was disappeared. The charred sample was incinerated in a muffle furnace at 550°C for 5 hours till the residue became white in appearance. The residue was moistened with few drops of deionized water and the water was allowed to evaporate on a hot plate. The sample was ashed for 30 minutes at 500°C and some drops of deionized water and 5 drops of concentrated HNO_3 was added after cooling in a desiccator. The water and HNO_3 were caused to evaporate on a hot plate as above starting from low temperature. The sample was again ashed as above for 30 minutes at the same temperature as previously described and it was weighed after cooling for 1 hour (W_3). The amount of total ash present in the sample was calculated by using the following formula.

$$ASh\ (\%) = \frac{W3 - W1}{W2 - W1} \times 100$$

Where,

W_1= weight of crucible, W_2= weight of crucible + sample, W_3= weight of crucible + ash,

W_2-W_1= weight of sample, and W_3-W_1= weight of ash

3.6. Mineral analysis

Mineral composition of the samples was determined according to methods recommended by Association of Official Analytical Chemists (AOAC, 2000) and ASEAN manual of food Analysis (ASEANFOODS, 2011). Ca, Fe, and Zn content of yam samples was determined by atomic absorption spectrophotometer (AAS) and K and Na content was determined by flame photometer following standard procedures.

3.6.1. Sample preparation for Ca, Fe and Zn

The yam samples were ashed following the procedure described above in the total ash analysis section. 7 mL of 6N HCl solution was added to the ash of each sample and heated on a low temperature hot plate until it dried. Then, 15 mL of 3N HCl solution was added and the mixture was heated on the hot plate till it just boils. After the solution cooled down, it was filtered through a filter paper into a volumetric flask (50 mL). Ten mL of 3N HCl was added and the crucible was heated until the solution boiled. The solution was allowed to cool and filtered through a filter paper into the volumetric flask. The crucible and filter paper was washed thoroughly and the washings were collected into the flask. Finally, 2.5 mL of lanthanum chloride was added into the solution and the volume was made up to the 50 mL mark with deionized water. Blank sample was also run by taking the same amount of reagents. The solutions were transferred to polyethylene bottles and stored in cool place until analysis.

3.6.2. Sample preparation for Na and K

1 g of yam flour was weighed on a filter paper and transferred into a 250 mL conical flask. Next, 20 mL of 1:1 dilute nitric acid was added and the mixture was boiled for about 10 minutes. The solution was cooled down to room temperature and filtered through a filter paper into a 100 mL volumetric flask. The conical flask and the filter paper were washed three times each with 10 mL of deionized water. The solution volume was made up to the 100 mL mark with deionized water and well mixed (Solution A). Blank solution was prepared from the same reagents and in the same amounts (Solution B). When diluting the solution for sodium analysis, 50 mL of solution A and B was pipette into volumetric flasks (100 mL) and 5 mL of dilute solution of potassium chloride was added. The volume was made up to the 100 mL mark with deionized water and thoroughly mixed (Solution C and D, respectively). For diluting the solution for sodium analysis, each 5 mL of solution A and B were transferred into 100 mL volumetric flasks and the solutions were made up to the mark with deionized water (Solution E and F).

3.6.3. Calibration curve and AAS analysis

In order to fit calibration curves, a series of standard solutions of the minerals were prepared from stock solutions of 20 ppm for Ca (0, 0.5, 2 4, 6, and 8), Fe (0, 0.5, 1, 2, 3, and 4), for Zn (0, 0.5, 1, 2,3 and 4 ppm), Na and K (2, 4,6, and 8 ppm). The flame atomic absorption spectroscope was calibrated with the prepared standards for the respective minerals and the sample solutions and also the blank were run to correct the obtained values. Finally, the mineral content of the samples were calculated by using the following formula. Sodium and potassium content of the samples were determined by flame photometer.

$$Mineral\ content\ \left({}^{mg}/_{100g}\right) = \frac{[(Cs - Cb) \times V \times D\,]}{10 \times W}$$

Where,

Cs = concentration sample, Cb = Concentration of the blank, V = volume (mL) of the extract and W = weight of samples, D= dilution factors.

$$Na\ content\ \left({}^{mg}/_{100g}\right) = \frac{(C - D) \times 200}{W \times 10}$$

$$K\ content\ \left({}^{mg}/_{100g}\right) = \frac{(E - F) \times 2000}{W \times 10}$$

Where,

W = weight (g) of sample

C and E = Concentration of the sample

D and F = Concentration of blank

3.7. Analysis of antinutritional factors

3.7.1. Phytate content

The phytate content of the raw and boiled yam samples was determined colorimetrically according to method described by Latta and Eskin (1988) as cited in Adane *et al*, (2013). About 0.1 grams of dried yam sample was extracted with 10 mL of 2.4% HCl for 1 hour at ambient temperature and centrifuged at 3000 rpm for 30 minutes. The clear supernatant was used for the phytate estimation. 1 mL of wade reagent (0.03% solution of $FeCl_3.6H_2O$ containing 0.3% sulfosalicylic acid in water) was added to 3 mL of the sample solution and the mixture was centrifuged. The absorbance at 500nm was measured using UV-VIS spectrophotometer. The phytate concentration was calculated from the difference between the absorbance of the control (3 mL of water and 1 mL of wade reagent) and that of assayed sample. The concentration of phytate was calculated using phytic acid standard curve (5, 9, 18, 27, and 36 ppm) and results were expressed as milligrams of phytic acid per 100 g dry weight. The following formula was used to calculate the phytic acid content of the samples.

$$Phytic\ acid\ \left({}^{\mu g}/_{100g}\right) = \frac{(Absorbance - intercept) \times 10}{Slope\ \times weight\ of\ sample \times 3}$$

3.7.2. Tannin content

Tannin content of the raw and boiled yam samples was determined using the method of Burns (1971) as cited in Adane *et al.* (2013). About 1g of yam flour was weighed in a screw capped test tube and 10 mL of 1% HCl in methanol was added to each test tube containing the samples. Next, the test tubes were shaked for 24 hours at room temperature using mechanical shaker. After 24 hours of shaking, the tubes were centrifuged at 1000×g for 5 minutes. One mL of the clear supernatant was taken and mixed with 5 mL of vanillin-HCl reagent in another test tube. Then, the mixture was allowed to stand for 20 minutes in order to complete the reaction. After 20 minutes the absorbance was read at 500nm using UV-VIS spectrophotometer. Finally, the concentration of tannins was calculated using D-catechin standard curve (0, 0.2, 0.4, 0.6, 0.8and 1 ml) or (0, 12, 24, 36, 48, and, 60mg/100g) and the results were expressed as catechin equivalent of tannins in milligram per 100 g dry weight. The following formula was used to calculate the tannin content of the samples.

$$Tannins\ \left(\frac{mg}{100g}\right) = \frac{[(Absorbance\ of\ sample - Absorbance\ of\ blank) - Intercept]}{Slope \times Density \times Weight\ of\ sample}$$

3.7.3. Oxalate content

The oxalate contents of both raw and processed yam flours were determined using the method of Iwuoha and Kalu (1994). This method involves the following three major steps; digestion, oxalate precipitation and permanganate titration.

Step 1: Digestion

About 2 grams of yam flour was suspended in 190 mL of distilled water contained 250 mL conical flask. Then, 10 mL of 6M HCl solution was added and the suspension was digested at 100°C for 1 hour. After cooling the suspension, the solution was made up to the 250 mL mark using distilled water and filtered into another flask.

Step 2: Oxalate precipitation

Duplicate portions of 125 ml of the filtrate were measured into a beaker and four drops of methyl red indicator was added, followed by the addition of concentrated NH_4OH solution in a drop wise manner until the test solution changed from its salmon pink çolor to a faint yellow color (pH 4-4.5). Each portion was then heated to 90°C, cooled and filtered to remove the precipitate containing ferrous ion. The filtrate was again heated to 90°C and 10 ml of 5% $CaCl_2$ solution was added while being stirred constantly. After heating, it was cooled and left overnight at 5°C. The solution was then centrifuged at a speed of 2500 rev/min for 5 min. The supernatant was decanted and the precipitate completely dissolved in 10 ml of 20% (v/v) H_2SO_4 solution.

Step 3: Permanganate titration

During this step, the total filtrate resulting from digestion of 2 g of flour was made up to 300 ml. Aliquots of 125 ml of the filtrate were heated until near-boiling, and then titrated against 0.05M standardized $KMnO_4$ solution to a faint pink color which persisted for 30 seconds. The calcium oxalate content was calculated using the formula:

$$Oxalate\ \left({}^{mg}/_{100g}\right) = \frac{T \times Vmeq \times DF \times 10^5}{ME\ \times Wf}$$

Where,

T is the amount of $KMnO_4$ consumed (ml),

Vmeq is the volume-mass equivalent in which 1 cm^3 of 0.05 M $KMnO_4$ solution is equivalent to 0.00225 g anhydrous oxalic acid),

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

ME is the molar equivalent of $KMnO_4$ in oxalate (5), and

Wf is the weight of flour used.

3.8. Data analysis

Analyses were done in duplicates for minerals and antinutritional factors and triplicates for proximate analyses to have of statistical analysis. Data was computed using SPSS (version 20) statistical software packages. Data were expressed as mean ± standard deviations of the replicate determinations. One way analysis of variance (ANOVA) was used to study the significant difference among the samples with respect to studied parameters. Least significant difference (LSD) at $P < 0.05$ was used to determine which means were significantly different.

4. Results and Discussion

The findings of this study are presented and discussed in detail to address the objectives of the research. All the data obtained from statistical analysis are stated on dry matter basis.

4.1. Proximate composition of raw and boiled yam tubers

Consumption of indigenous root and tuber crops is being encouraged worldwide as a means of meeting dietary needs of people. Tuber crops such as yams are significant source of digestible starch and as a result supply calories to the body (Onwueme, 1978). In addition, yam contains a substantial amount of minerals such as potassium, calcium, sodium, iron, and zinc. The proximate compositions of raw and boiled yam tubers of the present study are shown in Table 4.

4.1.1. Moisture content

Water is one of the vital constituents of foods which determine the structure, texture, appearance, taste, and shelf-life of foods (Fennema, 1996). Similar to other root and tuber crops, yam tubers are known for their high moisture content (Shajeela *et al.*, 2011; Adepoju, 2012). The moisture content of yam species ranged from 68.62% to 74.20% for raw tubers and from 72.14 to 77.64% for boiled tubers. The finding of this study is in line with the previous moisture contents reported for raw yam tubers, 58 to 79% (Polycarp *et al.*, 2012). There was no significant difference ($p>0.05$) between tubers of *hatiye* (68.62%) and *bunde-buchi* (69.33%) in percent moisture. *Wadala* had significantly higher moisture contents than *hatiye* and *bunde-buchi* in both raw and boiled forms. The variation in the moisture content of yam species might be due to the genetic differences that exist between them. Moisture content of the tubers increased significantly from raw to boiled tubers for the three species. The moisture content was increased by 6.38%, 4.43% and 4.05% for *hatiye, wadala*, and *bunde-buchi,* respectively. This increment in moisture content could be due to the high water absorption capacity of yam tuber constituents such as fiber and/or other physical or chemical changes during heat treatment that can enhance water uptake (Arias *et al.*,2003).

Table 4.1. Proximate composition and calorific value of raw and boiled yam tuber in dry weight basis except moisture analysis

Sample code	Moisture (%)	Crude protein (g/100g)	Crude fat (g/100g)	Crude fiber(g/100g)	Ash content (g/100g)	Carbohydrate content (g/100g)	Total energy(kcal/100g)
HR	68.62 ± 1.29^{d}	9.11 ± 0.33^{b}	0.55 ± 0.03^{bc}	2.20 ± 0.09^{d}	2.13 ± 0.00^{e}	86.00 ± 0.46^{a}	385.42 ± 0.19^{a}
WR	74.20 ± 0.91^{b}	10.1 ± 0.01^{a}	0.49 ± 0.00^{c}	1.21 ± 0.12^{e}	3.07 ± 0.00^{a}	85.10 ± 0.13^{b}	385.33 ± 0.49^{a}
BR	69.33 ± 0.61^{d}	8.76 ± 0.44^{b}	0.58 ± 0.01^{b}	2.25 ± 0.06^{d}	2.58 ± 0.00^{b}	85.83 ± 0.41^{ab}	383.61 ± 0.25^{b}
HB	73.00 ± 0.26^{bc}	7.41 ± 0.40^{c}	0.98 ± 0.05^{a}	3.94 ± 0.23^{b}	1.75 ± 0.01^{f}	85.93 ± 0.22^{a}	382.16 ± 1.08^{c}
WB	77.64 ± 0.35^{a}	8.56 ± 0.39^{b}	0.94 ± 0.06^{a}	3.20 ± 0.09^{c}	2.23 ± 0.01^{c}	85.07 ± 0.45^{b}	383.00 ± 0.22^{bc}
BB	72.14 ± 0.37^{c}	6.94 ± 0.46^{c}	1.00 ± 0.03^{a}	4.20 ± 0.14^{a}	2.17 ± 0.00^{d}	85.69 ± 0.58^{ab}	379.48 ± 0.61^{d}

- Values for all parameters are mean ± standard deviation of triplicate analysis
- Means with different letter superscripts in the same column are significantly different at $p<0.05$
- HR-Raw *hatiye*; WR- Raw *wadala*; BR-Raw *bunde-buchi*; HB-Boiled *hatiye;* WB-Boiled *wadala*; BB Boiled *bunde-buchi*

4.1.2. Crude protein content

Proteins are important macromolecules which serve astonishing variety of functions in living organisms. Root and tuber crops are generally considered to be low in protein content. However, yams have relatively high protein contents than other roots and tubers such as cassava. Based on the finding of this result, raw *wadala* tubers had the highest crude protein content of 10.13%refred by (Table 4.1). The protein content reported for yam tubers in this study was observed to be higher than previously reported figures, 7.82g/100g (Olajumoke, 2012), and 4.03-6.52% (Polycarp *et al.,* 2012) respectively. However, the crude protein content of the tubers was lower than protein content for *D. dumetorum* (11.41g/100g) and *D. alata* (10.27g/100g) which were reported by other studies (Ezeocha *et al.* 2012) and (Ezeocha *and* Ojimelukwe 2012), respectively. No significant differences were observed in protein contents between raw tubers of *hatiye* (9.11g/100g) and *bunde-buchi* (8.76g/100g) and also the protein content of boiled *hatiye* tubers (7.41g/100g) did not significantly differ from that of boiled *bunde-buchi* (6.94g/100g). *Wadala* had significantly higher protein contents than *hatiye* and *bunde-buch* in both raw and boiled forms. On the other hand, the protein content of the tubers was significantly decreased ($p<0.05$) from raw to boiled, by 18.66% (*hatiye*), 15.5% (*wadala*) and 20.78% (*bunde-buchi*). This reduction in crude protein content might be as a result of the loss of free amino acids which took place through leaching into the boiling water (Ezeocha and Ojimelukwe, 2012).

4.1.3. Crude fat content

Lipids are principal components of adipose tissue and together with other macromolecules constitute the major structural component of all biological cells. Lipids provide higher percentage of energy compared with carbohydrates and proteins. Roots and tubers including yams are very low in their lipid content. It was observed that raw tubers of yams contain 0.49 to 0.58 g/100g fats with raw *wadala* tubers being significantly the lowest refred by (Table 4.1). The fat content of raw tubers reported in this study was in close agreement with the results reported by Ezeocha *et al.* (2012), and Polycarp *et al.* (2012). However, Aflukwa *et al.* (2013) reported higher fat content (6.0g/100g and 13.03g/100g) which was much different from the values reported in the present study. Though the fat content of the tubers significantly increased from raw to boiled (by 72.4 to 91.8 g/100g), there was no significant difference among the three boiled yam species. Boiled *bunde-buch* had the highest crude fat content (1.00 g/100g) followed by *hatiye* (0.98 g/100g). The result of boiled tubers also agrees with the fat content reported by Adepoju (2012) and by Olajumoke *et al.* (2012) for *D. rotundata.*

4.1.4. Crude fiber

Dietary fiber is essentially defined as the sum of non-digestible components of a food stuff such as cellulose, hemicelluloses, resistant starch, pectic substances, lignin, hydrocolloids, and food gums which are the main components of plat cell wall (Anon, 2001). Optimum consumption of adequate fiber from a variety of foods is important for good health and therefore, their determination is important in terms of making food label claims. It can help to protect against constipation, colon cancer and also help to keep blood lipids within normal range, thereby reducing the risk of obesity, hypertension, and cardiovascular diseases in general (Salovaaara *et al.*, 2007). Numerous reports have shown that yam tubers are relatively low in their fiber content (Shajeela *et al.*, 2011; Polycarp *et al.*, 2012; Ezeocha and Ojimelukwe, 2012; Olajumoke *et al.*, 2012).

In this study, the crude dietary fiber content ranged from 1.21 to 2.25 g/100g for raw yam tubers and from 3.20 to 4.20 g/100g for boiled yam tubers refred by (Table 4.1). The findings of this research for the raw yam tubers agree with the previous results reported for the three yam species (Polycarp *et al.*, 2012). But the result for raw *bunde-buchi* disagrees with the crude dietary fiber content reported by Shajeela *et al.* (2011), 3.48 g/100g. In raw form, *bunde-buchi* had a significantly higher amount of crude fiber than *wadala.* It also had a significantly higher amount of crude fiber than the other two species in its boiled forms. The crude fiber contents of raw tubers of *hatiye* and *bunde-buchi* did not significantly differ from each other. During boiling, the crude fiber content increased considerably for all species, by 79.09%, 164.4% and 65.99% for *hatiye*, *wadala* and *bunde-buchi*, respectively. The observed increase in the crude fiber content of yam tubers could be due the loss of other soluble components of food during processing (in this case boiling) which subsequently resulted in increased crude fiber proportion of the food (Ahmed *et al.*, 2010). Therefore, boiling yam tubers can help in increasing their contribution to the dietary intake of crude fiber by humans.

4.1.5. Total ash content

The total ash, which is an indirect indicator of the mineral content of food stuffs, was found to be ranged from 2.13g/100g to 3.07g/100g for raw yam tubers and from 1.75g/100g to 2.23g/100g for boiled yam tubers as shown in (Table 4.1). The ash contents of *wadala* (3.07 and 2.23g/100g) and *bunde-buchi* (2.58 and 2.17g/100g) were significantly ($p<0.05$) higher than that of *hatiye* (2.20 and 1.75g/100g) both in raw and boiled forms. The finding of this study was in line with previous ash content reported for raw yam tubers which ranged from 2.25 to 3.15g/100g (Udensi *et al.*, 2010). However, another study reported slightly higher values of 8.15g/100g, 5.78g/100g and 4.90g/100g for *bunde-buchi, hatiye*, and *wadala*, respectively (Polycarp *et al.*, 2012). On the other hand, the ash content of the tubers was significantly decreased ($p<0.05$) from raw to boiled, by 17.8% *hatiye,* 39.4% *wadala* and 19.2% *bunde-buchi.* The observed decrease in ash content after boiling indicates that the minerals present in the tubers has been leached out to the boiling water (Ezeocha *and* Ojimelukwe, 2012).

4.1.6. Carbohydrate content

Carbohydrates are important in foods as major source of body fuel (energy) and contribute to a wide range of food attributes like taste, bulk density, viscosity, stability, color, aromas and textural properties (BeMiller, 2007). Yam species are rich source of carbohydrates in the form of dietary starch (Ugwu, 2009). The carbohydrate content of yam tubers ranged from 85.07g/100g for boiled *wadala* to 86.00g/100g for raw *hatiye* (Table 4.1). The values reported in this research for the raw tubers were found to be significantly higher than that of previous studies (Polycarp 2012; Shajeela et al., 2011; Ezeocha and Ojimelukwe, 2012). The carbohydrate content of raw tubers of *hatiye* (86.00g/100g) was significantly higher than that of *wadala* (85.10g/100g. Bunde-buchi in raw form had significantly lower than Wadala raw in carbohydrate content. Boiled tubers of *hatiya* also had appreciably higher amount of carbohydrate than boiled *wadala* (Table 4.1). On the other hand, the carbohydrate content of *hatiye* and *wadala* reduce slightly from raw to boiled. The reduction in the carbohydrate content of the tubers could be due to the leaching of soluble carbohydrates into the boiling water (Esenwah and Ikenebomeh, 2008).

4.1.7. Gross energy

Energy is required to sustain the body's various functions, including respiration, circulation, physical work, and maintenance of body temperature (Whitney and Rolfes, 2008). The raw yam tubers of *hatiye* (385.42 Kcal/100g) had high content of gross energy followed by *wadala* (385.33 Kcal/100g). However, boiled tubers of *bunde-buchi* (379.48Kcal/100g) had the least energy content than boiled *hatiye* (382.6 Kcal/100g) and *wadala* (383.0 Kcal/100g) tubers. No significant difference ($P>0.05$) in terms of energy values existed between *hatiye* and *wadala* both in raw and boiled forms, But *bunde-buchi* was significantly different from the rest species in terms of total gross energy. The amounts of gross energy reported in this finding were found to be relatively high when compared with those reported by Polycarp *et al.* (2012). Boiling had decreased the total energy content by up to 1.08%. The high carbohydrate and energy values of the yam tubers recorded in this study make them reliable food security crop.

4.2. Mineral Content of Raw and Boiled Yam Tubers

Minerals are naturally occurring elements other than C, H, O, and N that are present in foods. The human body doesn't produce minerals and they are obtained only from the foods we consume or the water we drink. Although they are present in relatively low concentrations in the body and foods, dietary minerals play indispensible roles in both living systems and foods (Fennema, 1996). Deficiency diseases could be prevented by sufficient intake of specific nutrients or minerals that are involved in many biological processes. Yam species are one of the important sources of minerals that are linked to prevent deficiency diseases (Aregahegn *et al.*, 2013). The mineral contents of raw and boiled yam are presented in Table 2.

Table 4. 2. Mineral content of raw and boiled yam tubers (mg/100g) dry weight basis

Sample code	Potassium	Sodium	Calcium	Iron	Zinc
HR	830.09 ± 29.87^{b}	32.88 ± 1.50^{a}	33.02± 8.63^{c}	2.02 ± 0.0^{a}	1.70 ± 0.02^{a}
WR	1029.62 ± 29.96^{a}	29.57 ± 1.49^{ab}	33.96± 8.46^{c}	1.09 ± 0.264^{c}	1.66 ± 0.05^{a}
BR	834.55 ± 30.03^{b}	21.56 ± 0.00^{c}	58.40± 10.39^{b}	1.64 ± 0.06^{abc}	1.59 ± 0.08^{ab}
HB	677.19 ± 30.42^{c}	20.79 ± 1.51^{c}	55.04± 11.90^{b}	2.20 ± 0.0^{a}	1.43 ± 0.09^{b}
WB	862.80 ± 32.62^{b}	27.76 ± 1.41^{b}	79.78± 1.25^{a}	1.15 ± 0.26^{bc}	1.66 ± 0.03^{a}
BB	717.51 ± 30.34^{c}	14.13 ± 1.56^{d}	81.95± 5.33^{a}	1.68 0.19^{ab}	1.50 ± 0.15^{ab}

- Values for all parameters are mean ± standard deviation of duplicate analysis
- Means not followed by the same superscript letters in the same column are significantly different ($p<0.05$)
- HR-raw *hatiye,* WR-raw *wadala*, BR- raw *bunde-buch,* HB-boiled *hatiye,* WB-boiled *wadala* BB-boiled *bunde-buchi.*

4.2.1. Potassium

Potassium is a major constituent in all living cells and is a major nutrient required in large amounts by plants, animals, and humans (Hamdallah, 2004). It plays an important role in nerve impulse conduction, muscle contraction, cell integrity, maintaining blood pressure as well as in acid-base balance (Whitney and Rolfes, 2008). The potassium contents of the three raw yam species were 830.09mg/100g, 1029.62mg/100g and 834.55mg/100g for *hatiye*, *wadala*, and, *bunde-buch*, respectively. There was no significant difference ($p>0.05$) between tubers of *hatiye* and *bunde-buchi* in potassium content. *Wadala* had significantly higher potassium contents than *hatiye* and *bunde-buchi* in both raw and boiled forms. The variations observed in this study may largely reflect the differences in genotype and maturity stag since all samples were obtained from the same cropping area. The values reported in this study are in line with the reports of Aregahegn *et al.,* (2013), potassium ranged from 847-1391mg/100g for *D. abyssinica*. High concentration of potassium in the tuber may be considered to be good for peoples with high blood pressure but may not be suitable for peoples with renal failure (Osagie, 1992). The finding of this study indicates that one can meet his/her daily requirements of potassium by consuming yam tubers.

4.2.2. Calcium

Calcium plays important structural and functional roles in the human body. It participates in mediating the constriction and relaxation of blood vessels and muscles and also involve in secretion of hormones and impulse transmission (Whitney and Rolfes, 2008). Calcium is the second most abundant mineral next to potassium among the minerals analyzed in this study. Its content was significantly high in boiled tubers than raw. Tubers of *bunde-buchi* (58.40g/100mg) had significantly higher amount of calcium than the raw forms of the other two species (Table 2). Moreover, no significant difference was observed between the calcium contents of *hatiye* (33.02mg/100g) and *wadala* (33.96mg/100g). The calcium content of the boiled yam tubers increased significantly. The increase in calcium content may be due to contamination. Boiled *bunde-buchi* (81.95mg/100g) had the highest calcium content followed by *wadala* (79.78mg/100g).

4.2.3. Sodium

Sodium is another important mineral analyzed in this study. The sodium content of yam species in this study ranged from 21.56mg/100g to 32.88mg/100g for raw tubers and from 14.13mg/100g to 27.76mg/100g for boiled tubers. The values are in agreement with the previous sodium contents reported for raw *D. abyssinica* tubers 13.30-40.50mg/100g (Aregahegn *et al.,* 2013). However, Aflukwa *et al.* (2013) reported lower sodium content range from 3.30mg/100g to 5.40mg/100g. Other studies also reported high sodium contents ranged from 62.5mg/100g to 102.5mg/100g (Polycarp *et al.,* 2012) and 44.56mg/100g to 168.24mg/100g).There was no significant difference ($p<0.05$) between tubers of raw *hatiye* and *wadala*. Raw *bunde-buchi* was significantly different from the rest species. On the other hand the sodium content of all three yam species decreased from raw to boiled by 36.8% for *hatiye*, 6.12 % *wadala* and 34.46 %*bunde-buchi*. This reduction in sodium content might be due to the fact that salts of sodium and potassium are more soluble in boiling water which is usually discarded (Adepoju, 2012).

4.2.4. Iron

Iron is one of the important minerals analyzed in this study. The iron contents of the raw *hatiye*, *wadala*, and *bunde-buchi* in this study were 2.02mg/100g, 1.09mg/100g and 1.64mg/100g respectively. There was no significant difference ($p>0.05$) between tubers of *hatiye* and *bunde-buchi* as well as tubers of *wadala* and *bunde-buchi* but there was significant difference ($p<0.05$) observed between tubers of *hatiye* and *wadala* in the present study of iron content. The finding of this study was in agreement with the previous iron contents reported for *dumetorum* (2.00mg/100g), *esculenta* (2.00mg/100g), *alata* (1.50mg/100g) but lower than those reported for other yam species which ranged from 5mg/100g for *rotundata* to 9mg/100g for *praehensilis* (Polycarp *et al.,* (2012). Values for iron in this study is also much lower than the value reported by Shajeela *et al.* (2011). From raw to boiled tubers, the iron content increased by for *hatiye* 8.18 % for 5.50% *wadala*, and 2.43% for *bunde-buchi*. The increase in the iron content may be due to contamination from cooking utensils as previously reported by Akin-Idowu *et al*., (2009).

4.2.5. Zinc

The zinc contents of raw yam tubers were 1.70mg/100g, 1.66mg/100g and 1.59mg/100g for *hatiye*, *wadala*, and *bunde-buchi*, respectively (Table 4.2). There was no significant difference between the three raw yam species in their zinc content. Raw tubers of *hatiye, wadala* and *bunde-buchi* were reported to have zinc contents of 5.85mg/100g, 5.80mg/100g and 6.35mg/100g, respectively; however, the zinc content in the current study for these species in contrast to with the stated values (Polycarp *et al.,* 2012). Aflukwa *et al.* (2013) reported much lower value than the present study with zinc content to be within the range of 0.25mg/100g to 0.26mg/100g for different yam species. The variation observed in this study may largely reflect the difference in genotype and maturity time. The treatment used (in this case boiling) in the current study decreased zinc content by up to 15 percent. The loss of zinc during boiling was insignificant in both *wadala* and *bunde-buchi* but significant in *hatiye*. The reduction of zinc content in boiled tubers may be due to leaching into and dispersion within the boiling water.

4.3. Antinutritional factors in yam tubers

4.3.1. Phytate Content

The phytate contents obtained from the three yam species in their raw and boiled forms are indicated in Table 3. The phytate contents of the raw yams were very low, with values ranging from 0.31 to 0.44 mg/100g. Although *hatiye* had relatively high phytate content, no significant differences were observed between the three species of yam both in raw and boiled forms. The phytate levels reported in this study are much lower than those of 0.89 to 4.26 mg/100g reported for yam tubers by Polycarp *et al.* (2012) and also are far below the values reported by Esayas (2006), 27.8 to 62.2 mg/100g. On the other hand, boiling of yam tubers resulted in slight but not significant reduction of phytate content. The phytate contents of *hatiye, wadala* and *bunde-buchi* tubers were reduced from raw to boiled by 38.6%, 29% and 16.7%, respectively. The reduction in phytate during boiling may be caused by leaching into the boiling water, degeneration by heat or the formation of insoluble complexes between phytate and other components, such as phytate-protein and phytate-protein-mineral complexes (Bhandari *et al.,* 2004). The low phytate content of these yam species indicates that they are good source of bioavailable minerals. A high content of phytate in plant foods results in the reduction of the bioavailability of dietary minerals such as calcium, iron, zinc and divalent metals. However, currently there are evidences that dietary phytate at low level may have beneficial role for lowering blood glucose and hormonal responses, reduction of blood lipids and reduction of the risk of cancer (Thompson, 1993).

4.3.2. Tannin Content

Table 3 shows results of tannin determination in the three raw and boiled yam species. The tannin content of raw yam species in this study was 0.75 mg/100g, 0.83mg/100g, and 3.49 mg/100g for *Hatiye*, *Wadala* and *bunde-buchi*, respectively. The tannin content reported for raw yam tubers in this study was observed to be significantly lower than previously reported results, 4.40 – 13.20 mg/100g (Polycarp *et al.,* 2012). However, the tannin concentration reported in this study agrees with the values reported by Shajeela *et al.* (2011) that ranged from 0.04-1.48mg/100g. There was no significance difference ($p<0.05$) between tubers of *hatiye* and *wadala* in tannin content. Bunde-buchi has significantly higher tannin contents than hatiye and *Wadala* in both raw and boiled forms. Tannin content of the tuber decreased from raw to boiled tubers for the three species though it was insignificant. The tannin content decreased by 49.8 %, 61.4% and 31.8% for *hatiye, wadala* and, *bunde-buchi*, respectively. The decreases in the levels of tannin during heat treatment might be due to thermal degradation and denaturation of the antinutrients as well as the formation of insoluble complexes (Kataria *et al.,* 1989). Tannins were long known to exert negative effect on the bioavailability of proteins, minerals and particularly iron. In most foods the tannin content reduction by processing method like boiling has been reported to enhance the bioavailability of iron. The toxicity effects of the tannin may not be significant since the total acceptable tannic acid daily intake for human is 560mg (Anonymous, 1973). Since the tannin contents of raw yam tuber in the present study were too low compared to its critical toxicity effect and had been reduced during boiling, its antinutritional effect may be insignificant in both raw and processed tuber to cause any adverse effect on the consumers.

Table 4. 3. Antinutritional factors content of raw and boiled yam species (mg/100g) dry weight basis.

Sample code	Phytate	Oxalate	Tannin (Catechin)
HR	0.44 ± 0.06^{a}	0.63 ± 0.08^{bc}	0.75 ± 0.03^{b}
WR	0.31 ± 0.04^{ab}	0.78 ± 0.10^{ab}	0.83 ± 0.15^{b}
BR	0.36 ± 0.02^{ab}	1.06 ± 0.11^{ab}	3.49 ± 1.35^{a}
HB	0.27 ± 0.05^{ab}	0.43 ± 0.07^{cd}	0.28 ± 0.02^{b}
WB	0.22 ± 0.10^{b}	0.34 ± 0.07^{d}	0.32 ± 0.12^{b}
BB	0.30 ± 0.07^{ab}	0.85 ± 0.20^{ab}	2.38 ± 0.15^{a}

- Values for all parameters are mean ± standard deviation of duplicate analysis
- Means not followed by the same superscript letters in the same column are significantly different ($p<0.05$)
- HR-raw *hatiye,* WR-raw *wadala*, BR- raw *bunde-buch,* HB-boiled *hatiye,* WB-boiled *wadala* BB-boiled *bunde-buchi.*

4.3.3. Oxalate Content

Oxalate contents of raw and boiled three yam species are shown in Table 3. The content of oxalate in raw tubers ranged from 0.63mg/100g to 1.06 mg/100g.There was no significance difference ($p>0.05$) between the raw forms of the three species in their oxalate content. However, bunde-buchi had relatively high oxalate content. The oxalate level reported in this study is slightly higher than the values reported by Polycarp et al. (2012) for yam tubers, 0.20g/100g to 0.58 mg/100g. On the other hand, the oxalate level present in raw bunde-buchi tubers (1.06mg/100g) is in agreement with the previous oxalate values reported for raw white guinea yam (D. rotundata) tubers, 1.07mg/100g (Olajumoke, 2012).Oxalates can have deleterious effect on human nutrition and health particularly by decreasing calcium absorption and causing the formation of kidney stones (Noonan and Savage.,1999). In the present study, boiling reduced oxalate content of the yam tubers by 46.5%, 29%, and 24.7% percent for *hatiye, wadala* and *bunde-buchi*, respectively. The reduction of oxalate levels by boiling is expected to enhance the bioavailability of essential minerals of yam and reduce the risk of kidney stone formation among consumers. Therefore, the reduced oxalate content in boiled yam tubers could have positive impact on the health of the consumers. The reduction of oxalate content by boiling may be due to considerable cell rupture and facilitates the leakage of soluble oxalate in to cooking water (Bhandari *et al.,* 2004). Currently, nutritionists recommend to patients the intake of foods with a total amount of oxalate not exceeding 50-60mg/per day (Oladimeji *et al.*, 2000). Boiled yam tubers analyzed in this study are low in their oxalate contents compared to the recommendations for patients with calcium oxalate kidney stones. Therefore, boiled yam tubers could be recommended not only for normal healthy people, but also for patients with a history of calcium oxalate kidney stones.

4.4. Molar Ratios of Antinutritional Factors to Minerals

The molar ratios between the antinutritional factors (phytate and oxalate) and the analyzed minerals i.e., iron, zinc and calcium were calculated to evaluate the effects of elevated levels of phytate and oxalate on the bioavailability of dietary minerals. The calculated values were also compared with the reported critical toxicity values for these ratios. Bioavailability may be defined as the ability of the body to digest and absorb the mineral in the food consumed. The calculated values for Phytate/iron, Phytate/Zn, Phytate /Ca and Oxalate/Ca molar ratios of raw and boiled yam tuber are shown in Table 4.5.

The Phytate/iron molar ratios of raw *hatiye*, *wadala*, and *bunde-buchi* were 0.19, 0.25, and 0.19 for raw tubers and 0.1, 0.16, and 0.16 for boiled tubers in that order and with no significant differences among the raw as well as boiled tubers. Boiling treatment reduced the phytate: iron molar ratios although it was not significant. The phytate: iron ratios greater than 0.15 are regarded as an indicator of poor iron bioavailability (Siegenberg *et al.*, 1991).The result of this study indicated that the phytate: iron molar ratios for both raw and boiled yam tubers were greater than the critical value except for boiled *hatiye* tubers. This implies that the absorption of iron from raw and boiled yam species could be inhibited by phytate and as a result the bioavailability of iron is poor. Therefore, selection of appropriate processing methods which may result in low phytate/iron ratios would be beneficial.

Table 4. 4. Molar ratios between antinutritional factors and selected minerals

Sample code	Phytate : Fe	Phytate : Zn	Phytate : Ca	Oxalate : Ca
HR	0.19±0.06^{ab}	0.53±0.42^{a}	0.009±0.001^{a}	0.01±0.001^{a}
WR	0.25±0.06^{a}	0.19±0.02^{a}	0.003±0.000^{c}	0.01±0.001^{bc}
BR	0.19±0.01^{ab}	0.23±0.01^{a}	0.003±0.000^{c}	0.01±0.001^{b}
HB	0.10±0.01^{b}	0.19±0.01^{a}	0.005±0.001^{b}	0.01±0.001^{cd}
WB	0.16±0.05^{ab}	0.52±0.47^{a}	0.003±0.001^{c}	0.003±0.00^{d}
BB	0.16±0.00^{ab}	0.20±0.28^{a}	0.003±0.001^{c}	0.01±0.001^{cd}

- Values for all parameters are mean ± standard deviation of duplicate analysis
- Means not followed by the same superscript letters in the same column are significantly different ($p<0.05$)
- HR-raw *hatiye,* WR-raw *wadala*, BR- raw *bunde-buch,* BH-boiled *hatiye,* BW-boiled *wadala* BB-boiled *bunde-buchi.*

The molar ratios of Phytate: Zn for yam species ranged from 0.19 to 0.53 for raw yam tubers and 0.19 to 0.52 for boiled yam tubers. There were no significant variations ($p>0.05$) between the molar ratio of the three species both in raw and boiled yam forms. The value of both raw and boiled yam tuber were lower than critical molar ratio of phytate to zinc, which indicates the high bioavailability of zinc the tubers. In the present study, the molar ratios of phytate/calcium and oxalate/calcium were found to be very lower than the reported critical value for molar ratios of phytate/calcium,>6 (Oladimeji *et al.*, 2000) and oxalate/calcium, >1 (Frontela *et al.*, 2009). This indicates that the phytate and oxalate found in these tubers cannot adversely affect the bioavailability of calcium.

4.5. Comparison of contents of nutritional and antinutritional factors in raw yam species with other root and tuber plants in dry weight basis.

Results of the present study are compared with other root and tuber crops grown in other parts of the world where Taro, Cassava and Anchote used as staple food (Table 5). Like other root and tuber crops, yam species has higher moisture content. It is evident from the data that the raw yam species contain 1.45, 7.07 and 2.87 times higher protein compared to taro, cassava and anchote respectively. Bradbury and Holloway (1988) reported yam tuber contains approximately four times as much protein as cassava which is lower than the present study. This indicates that the tubers of yam species may be another cheap source of protein for individuals who are taking this plant regularly as a staple and co-staple food. The raw yam tuber contains low crude fat which is similar to other root and tuber crops. This finding confirms the reports of Polycarp *et al.,* (2012), that yam tuber contains a low crude fat content. The crude fiber in yam tubers is lower than taro, cassava and anchote. The total ash contents in yam tuber are also relatively high compare with anchote. This implies that yam tuber is a potential source of minerals than other mentioned plants. From the present results it can also be noted that yam tuber is a good source of carbohydrates. The carbohydrate contents of yam tuber in this study (85.64g/100g) were comparable to carbohydrate contents of taro (85.65g/100g), but lower than cassava and anchote. In addition, raw yam tubers have higher gross energy contents (384.78 Kca/100g) compared to all the above mentioned root and tuber crops. This quantity of energy makes yam tuber one of the most carbohydrate rich foods in supplying high quantity of energy per a given mass of food consumed and make them reliable food security crops. Comparing the distribution of minerals in yam tubers with other root and tuber crops yam tuber consist of an appreciable amount of K, Ca, Na, Fe, and Zn like other root and tuber crops. However, its distribution is not follow common trend some of the minerals (like Ca, Fe, Zn) were highest in taro, sweet potato, and anchote while lower were noticed for the mineral Na.

It has been reported that few yam species contain some toxic compounds and can impose serious health complications (Anthony, 2004). In this investigation, unlike other root and tuber crops yam tuber contains very law amount of phytate (0.37mg/100), tannin (1.69mg/100g), and oxalate (0.82mg/100g). Except cassava (1.70 mg/100g) comparable result in tannin content with yam tubers all the above mentioned root and tuber crops contain very high amount of antinutritional factors. In generally in this study most of antinutritional factors are low to cause health hazard and the overall results are suggestive of high nutritional quality of the yam tubers compared with the above mentioned root and tuber crops due to very low content of antinutritional factors and good source of protein and essential minerals.

Table 4. 5. Comparison of the nutritional value and antinutritional factors of yam species with other root and tuber crops

Parameter	Yam spp.[1]	Taro[2]	Cassava[3]	Anchote[4]
Moisture (g/100g)	70.71	NF	NF	74.93
Protein g/100g)	9.33	6.44	1.32	3.25
Fat(g/100g)	0.54	0.47	0.88	0.19
Fiber (g/100g)	1.89	2.62	3.44	2.58
Ash (g/100g)	2.59	4.82	3.45	2.19
Carbs (g/100g)	85.64	85.65	90.55	92.11
Energy(Kca/100g)	384.78	372.56	376.86	382.78
Ca (mg/100g)	41.79	45.33	NF	119.5
Na (mg/100g)	28.00	13.81	NF	NF
Fe (mg/100g)	1.81	5.86	1.34	5.49
Zn (mg/100g)	1.65	43.08	ND	2.23
Phytate (mg/100g)	0.37	115.43	543.97	389.3
Tannin(mg/100g)	1.69	47.69	1.70	174.55
Oxalate (mg/100g)	0.82	243.06	24.93	8.23

1 = average of yam spp. : 2 = Adane *et al.*, (2013) : 3 = Tilahun Abera (2009) : 4=Habtamu Fekadu, (2011) : NF = not found : ND = not detected.

4.6. Sensory acceptability of yam species

It is well known that the sensory properties of a food product are important determinants of its acceptability and preference among consumers. In the present study a consumer panel consisting of 15 judges tested boiled tubers of yam species for their color, taste, aroma, texture and overall acceptability. The results showed significant differences ($p<0.05$) in the consumer preference for most of the attributes of the boiled yams (Table 6). *Hatiye* was the most preferred species for its color, taste, aroma, and overall acceptability. On the other hand, *bunde-buchi* was the least preferred species for almost all attributes evaluated. Generally, sensory evaluation of boiled yam tubers indicated that yam consumers in the study area have preference towards *hatiye*. The reason they prefer this species could be because the landraces of *hatiye* are popular in the study areas due to their sweet taste and white tuber flesh color (Tamiru *et al.*, 2008). Some consumers commented on their reason to prefer this species and they revealed that the white flesh color of *hatiye* goes well with the milk when preparing yam based traditional delicious food called fichata.

Table 4. 6. Sensory acceptability evaluation of yam species

Yam sample	Color	Taste	Aroma	Texture	Overall acceptability
Hatiye	6.53^{a}	6.53^{a}	6.20^{a}	6.53^{a}	6.87^{a}
Wadala	5.80^{b}	5.47^{b}	5.67^{ab}	5.80^{b}	6.00^{b}
Bunde-buchi	4.67^{c}	5.07^{b}	5.27^{b}	5.33^{b}	5.53^{c}

- Means not followed by the same superscript letters in the same column are significantly different ($p<0.05$)
- HR-raw *hatiye,* WR-raw *wadala*, BR- raw *bunde-buch,* HB-boiled *hatiye,* WB-boiled *wadala* BB-boiled *bunde-buchi.*

5. Conclusion and Recommendations

5.1. Conclusion

In general, the nutritional composition, antinutritional factors and sensory acceptability of the yam tubers were influenced by the genetic variations and maturity time among the species. The tubers of *wadala* were better in protein and total ash contents but were the least in fiber and crude fat contents. The tubers of *bunde-buchi* were good in fat and fiber contents when compared with the other two species. *Hatiye* were relatively highest in total carbohydrate content. With respect to antinutritional factors, *hatiye* contained high phytate contents and *bunde-buchi* had high oxalate and tannin contents. The tubers of *wadala* were comparatively the least in the contents of all antinutritional factors. On the other hand, high potassium content was recorded for *wadala* and the tubers of *hatiye* were better in their sodium, iron and zinc levels. The tubers of *bunde-buchi* were good in calcium content than other species tubers. The tubers of *hatiye* were the most preferred in almost all sensory attributes and *bunde-buchi* were the least preferred species.

The results of this study indicate that the three yam species can contribute to the daily intake of macronutrients and minerals. The low content of the antinutritional factors in yam species also makes them potential food for the rural people. The nutrient contents reported for the three species were higher when compared with other root and tuber crops such as taro, cassava, sweet potato, and anchote. The low molar ratios between the antinutritional factors and minerals also indicate that trace minerals particularly Zn and Ca cannot be adversely affected by these factors.

5.2. Recommendation

Findings of this study have potential to promote the production and diversification of these three species consumption in Ethiopia especially in the Southern region. The tubers should, therefore, be granted their fair position as sources of food in the future and other feasibility studies should be conducted in other regions of the country to exploit its potential for nutrition security and sustainable development. Future priority and research in the area of yam species should lie in selection of proper processing methods to diversify their utilization and better reduce the antinutritional factors present in them with no nutrient loss. Agriculturalists should also help in distributing, adaption and biofortification of the yam species. In conclusion, consumers should not only focus on the sensory attributes of the yams, instead they should understand the nutrient profile of the species to make informed choices. This is because while wadala tubers were high in most nutrients, people in the study area prefer hatiye over other species due to its white color and thus, it calls for awareness creation among the consumers. The yam tubers should also be tested for their glycemic index to be used by diabetic patients.

References

Abera, T. (2009). Effect of processing methods on some physicochemical composition and Antinutritional Factors of locally grown Cassava *(Manihot esculenta* Crantz) varieties. MSc. thesis report, Addis Ababa University, Ethiopia.

Abraham, K. (1998). Occurrence of Hexaploid Males in *Dioscorea alata L.* Kluwer Accademic Publisher, Central Tuber crops Research Institute, India, 99:5-7

Addis, T. (2005). Biology of enset root Mealybug (*Cataenococcus Ensete*) Williamsand Matileferrero (Homoptera: Pseudococcidae) and its geographical distribution in southern Ethiopia. M.Sc. Thesis, Alemaya University, Alemaya, Ethiopia.

Adepoju, O.T (2012) Effects of processing methods on nutrient retention and contribution of white yam (*Dioscorea rotundata*) products nutritional intake of Nigerians Journal of food science (6): 163-167

Adane, T., Shimelies, A., Negussie, R., Tilahun,B., Gulelat, D. (2013). Effect of processing method on the proximate composition, mineral content and antinutritional factors of taro *(Colocasia esculenta,L)* grown in Ethiopia. African Journal of food and Agriculture, Nutrition and Development 13(2): 383-398

Aflukwa, C.A., Ogah,O., Uguw Okechukwu, P.C ., Oguguo, J.O.,All, F.U., Ossal Emmanuel, C.C (2013).Nutritional and Antinutritional Characterization of two wild yam species from Abakalki, southeast Nigeria. Journal of pharmaceutical, Biological and chemical Sciences. 4(2):840

Ahmed, A.,Bebbe.,F.,Clerge,T.,Clement, S. and Mohammadous, B. (2010). Physico-chemical and functional properties of batchi or hypocotyle axes of borassus aethiopum Mart. African Journal of food Science 4(10): 635-641.

Akin-Idowu, P. E., Asiedu, R., Maziya-Dixon, B., Odunola, A. and Uwaifo, A. (2009). Effects of two processing methods on some nutrients and anti-nutritional factors in yellow yam *(Dioscorea cayenensis). African Journal of Food Science* , 3, 022- 025,.

Anon. (2001). The definition of dietary fiber. Cereal Foods World 46:112

Anonymous(1973). Tannic acid gain. Food cosmetol Toxicol. In: Toxicants Natural occurring in foods. National Accademy of sciences. Third Edition. Pp112

Anthony, C. (2004).The wild yams: A review. [Retrieved from: http://www.deveckdata.com /plant_month_files Y wild.yam.htm.]

Anthony,C.(2004).Thewildyams:Areview.http://www.deveckdata.com/plant_month_filesYwild. yam.htm.

AOAC, (2000). Association of Official Analytical Chemists. Official methods of Analysis Vol.II 17th edition Washington, DC, USA, *Official methods 925.09,923.03, 979.09, 962.09, 4.5.1, and 923.05.*

Aregahegn, A., Chandravanshi, B.S. & Atlabachew, M. (2013).Levels of major, minor and toxic metals in tubers and flour of *Dioscorea abyssinica* grown in Ethiopia. *African J. of Food, Agri. Nutr. Dev.,* 13 (3): 7870-7887

Arias, M.T.G Potnes, E.A., Fernandez, M. C. G. and Muniz, F. J. S. (2003). Freezing/boiling/frying of sardine fillets. Influence of slow and quick defrosting on protein quality. Journal of the science of Food and Agriculture, 83, 602-608.

Arinathan, V. Mohan, V.R. and Maruthupandian, A. (2009). Nutritional and antinutritional attributes of some under –utilized tubers. Tropical Subtropical Agroecosystems. 10: 273-278.

ASEANFOODS. (2011). *The ASEAN manual of food analysis.* (1st ed.), Institution of nutrition, Mahidol University, Thailand.

Asemota, H.N and Osagie, A.U. (1993). Carbohydrate metabolism in stored yam tubers: Contribution of starch break down glycolysis and pentose phosphate pathwa. In:Osuji,G(Ed), Advances in Yam Research (pp 135-44).Texas: Prairie View AandM

Ayele, E. (2009). Effect of boiling temperature on mineral content and antinutritional factors of yam and taro grown in Southern Ethiopia. MSc. thesis report, Addis Ababa University, Ethiopia.

Behera, K.K, Maharana, T., Santilata, S. and Prusti, A. (2009) Biochemical quantification of Protein, fat, starch, Crude fiber, ash, and dry matter content in different collection of Greater Yam (Dioscorea alata L.) found in Orrisa. Deptt.of Botany, Utkal University, Orrisa, India, Natu*re and Science 7: 0545-0740

BeMiller, JN (2007). Carbohydrate chemistry for food scientists, 2nd edn. AACC Internationa St.Paul, MN

Bhandari, M.R. and Kawabata, G. (2004). Organic acids, Phenolic content and anti-oxidant Activity content of wild yam (Dioscorea species) Tubers of Nepal. FoodBiochemistry Laboratory Division of Applied Bioscience, Hokkaido University, Japan 88:163-168

Bhandari, M.R., Kasai, T. and Kawabata, J. (2003).Nutritional evaluation of wild yam (*Dioscorea* spp.) tubers of Nepal. *J. Food Chemistry,* 82(4): 619–623.

Bradbury, J.H .and Holloway, W.D. (1988).Chemistry of tropical root crops: significance for nutrition and agriculture in the Pacifi. ACIARMonograph No. 6. Australian Centre for International Agricultural Research: Canberra.

Coursey, D.G. (1973). Cassava as food toxicity and technology. In: Nestel B and McIntyre R (eds) Chronic cassava toxicity. Proceedings of Workshop, London, pp. 27–36.

Demel, T. Feyera, S. Million, B., Maclachlan, M. and Barklud, P. (2010). Edible Wild Plant in Ethiopia, Addis Ababa University, Press; 149-156

Eddy, N.O. and Eyo, D. (2007). Sensory evaluation of wheat cassava composite breed and effect of lable information on acceptance and preference. African journal of biotechnology 6(20) 2415-2418.

Esenwah, C.N., and Ikenebomeh, M.J.,(2008). Processing effect on nutritional and Antinutritional contents of African Locust Bean (Parkia biglobosa Benth.) seed.pakistan Jornal of Nutrition,7(2):214-217.

Ezeocha, V. C. and Ojimelukwe, P. C. (2012). The impact of cooking on the proximate composition and anti-nutritional factors of water yam (*Dioscorea alata*). *Journal of Stored Products and Postharvest Res.,* 3(13). pp. 172 – 176.

Fekadu, H., Beyene, F., Desse, G. (2014). Evaluation of bioavailability and sensory preferences of processed Anchote *(Coccinial Abyssinica)* tubers in eastern Wollega, Ethiopia. Journal of Food and Nutrition Sciences. 2(1); 1-2.

FAO . (2005). Food and Agriculture organization. Statistical data. www.fao.org.

FAO. (1997). Food and Agricultural Organization: *Food Production Yearbook*, 50:160-168.

FAO. (2009). Production indices and Pops TAT. FAO, Statistics Division. [Retrieved from: <http://faostat.fao.org/default.aspx>. Accessed on 8 December 2009.]

Fronteal, C., Scarino, M.L., Ferruzza, S., Ros, G. and Martinez, C. (2009). Effect of dephytinization on bioavailability of iron, calcium and zinc from infant cereals assessed in the Caco-2 cell model. World Journal of Gastroenterology, 28:1977-1984.

Grusak, M.A. and Penna, D.D. (1999). The nutrient composition of plants to enhance human nutrition and health. *.Annual Review of Plant Physiology and Plant Molecular. Biology,* 50: 133–161.

Guyot, J.P., Rochette, I and Treche, S. (2007). Effect of fermentation by amylolytic lactic acid bacteria, in process combinations, on characteristics of rice /soybean slurries: A new method for preparing high energy density complementary foods for young children. Food Chemistry, 100 :623-663.

Hahn, S.K. (1995). Yams, *Dioscorea* spp.(Dioscoreaceae). In 'Evolution of crop plants', Longman Scientific and Technical: London: 112–120

Hariprakash, C. S. and B. Nambisan (1996). Carbohydrate metabolism during dormancy and sprouting in yam *(Dioscorea*) tubers: changes in carbohydrate constituents in yam (*Dioscorea*) tubers during dormancy and sprouting. Journal of Agricultural and Food Chemistry 44, 3066-3069.

Hildebrand, E., Demissew, S., Wilkin, P. (2002). Local and regional disappearance in species of Dioscorea L (Yams) in southwest Ethiopia. In: Stepp JR, Wyndham FS, Zarger RR (eds) Ethnobiology and biocultural diversity. Proceeding of the 7th international congress of ethno biology. University of Georgia Press, USA: 678–695

Horrocks, M., Grant-Mackie, J and Matisoo-Smith, E. (2008). Introduced taro *(Colocasia esulenta)* and yams *(Dioscorea spp.) in* podtanean (2700el 1800 years BP) deposits from Me Aure Cave (WMD00), Moindou, New Caledonia. Journal of Archaeological Science, 35,169-180

IITA (2009). On the Estimation of Technical Inefficiency in the Stochastic Frontier Production Function Model. *Journal of Econ,* 19:233 – 238. [Retrieved from: http.//www.iita.org; Accessed on July 21, 2010]

Iwuoha, C.I. (2004). Comparative evaluation of the physio-chemical characteristics of flours from steeped tubers of white yam *(Dioscorea rotundata poir),* Water yam *(Dioscorea alata L.)* and yellow yam *(Dioscorea cayenensis Lam).*22 (2): 56-63.

Janardhanan, K. (1990).Germplasm resources of pulses of tribal utility in India. In: Proceedings of the National Seminar on Advances in Seed Science and Technology Eds. H.S. Shetty and H.S.Prakash.December14-16,.University of Mysore, India. pp 407-709.

John, M. deMan. (1999).Principles of Food Chemistry.3rd ed. Aspen Publishers, Inc., Gaithersburg, Maryland. pp 111-152

Kataria, A., Chauhan, BM. and Punia, D. (1989). Antinutrients and protein digestibility (in Vitro) of mungbeans as affected by domestic processing and cooking. Food Chem. 3:9-17.

Kays, S.J. (1997). Post harvest physiology of perishable plant products. Exon press, Athens, Greek.

Kochar, J. (1998). Economic botany of the tropics. 2nd ed. Macmillan, India Ltd., India.

Komesaroff, P.A,. Black, C.V,. Cable, V, and Sudhir, K,.(2001).Effects of wild yam extract on menopausal symptoms, lipids and sex hormones in health menopausal women. Climacteric 4: 144-50.

Lagegmann. J. (1977). Traditional African Farming Systems in Eastern Nigeria. Welt forum Verlag, Munich, Germany.

Lawal, O., A Agiang, M. & U Eteng, M. (2012). Proximate and anti-nutrient composition of white Guinea yam (*Dioscorea rotundata)* diets consumed in Ibarapa, South West region of Nigeria. *Journal of Natural Production Plant Resource*, 2 (2):256-260

Lawless, H.T., & Klein, B.P. (1989). Academic vs. Industrial Perspective on Sensory Evaluation. *Journal of Sensory Studies, 3,* 205-216.

Lebot, V. (1999). Bimolecular evidence for plant domestication in Sahul. Genetic Resources and Crop Evolution 46, 619–628.

Lebot, V., Malapa, R., Molisade, T., and Machad J.L. (2005). Physicochemical characterization of yam (*D. alata* L.) tubers from Vanuatu. Genetic Resources and Crop Evolution.

Liener, I..E. and Kakade, M.L. (1980).Protease inhibitors .In: Toxic constituents of plant food stuffs I.E (Ed) . Academic Press, New York, London, Toronto, Sydney, San Francisco pp: 7-71.

Maneenoon, K., Sirirugsa, P. &Sridith, K. (2008).Ethnobotany of *Dioscorea* L. (Dioscoreaceae), a major food plant of the Sakai tribe at Banthad Range, Peninsular Thailand.Ethnobot any Research and Applications, 6: 385-394.

Meilgaard, M.C., Carr, T., and Civille, G. (1999). *Sensory Evaluation Techniques* (3 rd ed.) New York: CRC Press Inc

Mie´ge, J., Demissew, S. (1997). Dioscoreaceae. In: Hydrocharitaceae to Araceae (Edwards, S. Demissew, S., Hedberg I eds). Flora of Ethiopia & Eritrea, Vol 6, Addis Ababa, Ethiopia, and Uppsala, Sweden, pp 55–62

Mignouna H.D., Abang M.M., Wanyera N.W., Chikaleke V.A., Asiedu R. and Thottappilly,G. (2005). PCR marker-based analysis of wild and cultivated yams (*Dioscorea* spp.) in Nigeria: genetic relationships and implications for exsitu conservation. Genetic Resources and Crop Evolution 52, 755–763.

Mignouna, H.D., Abang, M.M., Asiedu, R. (2004). Harnessing modern biotechnology for tropical tuber crop improvement: yam (*Dioscorea* spp.) breeding. *Afr. J. Biotechnol.*, 2(12):478-485.

Morris,E.R and Ellis,R (1989). Usefulness of the dietary phytic acid/zinc molar ratio as an index of zinc bioavailability to rats and humans. Biol Trace Element Res 19; 107-117

O'Sullivan, J.N. (2010). Yam nutrition: nutrient disorders and soil fertility management. ACIAR Monograph No. 144. Australian Centre for International Agricultural Research: Canberra. 112 pp. ACT 2601, Australia

Oladimeji, M.O., Akindahunsi, A.A., and Okafor, A.F. (2000). Investigation of the bioavailabilit of zinc and calcium from some tropical tubers.Nahrung,44,136–137(Nr2, S).

Olajumoke, O.L., Margaret, A.A and Mbeh,U.E. (2012). Proximate and anti-nutrient composition of white Guinea yam (Dioscorea rotundata) diets consumed in Ibarapa, South West region of Nigeria. Journal of Nat.Production Plant Resource. 2(2):256-260

Onwueme, I.C. (1978). The tropical tuber crops, Yam, Sweet potato, Cocoyam. John Willey and Sons Ltd, New York. Pp 86-87.

Osagie, A.U (1992). The yam storage post harvest research Unit,Universsity of Benin, Nigera.

Owen R. Fennema. (196). Food Chemistry.3rd ed. Marcel Dekker, Inc. New York, USA. pp 321-425

Polycarp, D., Afoakwa, E. O., Budu, A. S. and Otoo, E. (2012). Characterization of chemical composition and anti-nutritional factors in seven species within the Ghanaian yam *(Dioscorea)* germplasm. *Int. Food Res. Journal,* 19 (3): 985-992

Prakash, D., Nath, P. and Pal, M. (1993). Composition, variation of nutritional comntents.

Prevolotsky, A. (1994). Tannins in Mediterranean wood lands species: lack of response to browsing and thinning. Oikos 71, 333-340.

Raemaekers, R.H. (2001) Crop Production in Tropical Africa. Ministry of Foreign Affairs, Belgium 229-239

Ravi, V., Ked, J. and Balagopalan, C. (1996). Review on tropical root and tuber. In: *Critical Reviews. Food Sci. Nutr.*; 36: 360–730.

Redden, R.J., Chen, W., & Sharm, B.(2005).Chick pea Breeding and Management. United Kingdom: CABI.

Rosalind, S., Gibson, M., Leah, P. and Christine, H. (2006). Improving the bioavailability of nutrients in plant foods at house level. Department of human Nutrition, University of Otago, Dunedin, New Zealand. *Proceedings of the Nutrition Society*; 65:160-168.

Salovaara, H., Gates., F., Tenkanen., M. (2007). Dietary fibre components and functions. Wageningen Academic, Wageningen, the Netherlands

Schultz, G.E. (1993). Element Stewardship abstract for Dioscorea bulbifera Air potato. The nature of conservancy; University of Florida, Florida museum of natural History. 703:1-9.

Scott, G.J., Rosegran, M.W. and Ringler, C. (2000). Global projections for root and tuber crops to the year. *Food policy,* 25: 561-597.

Shajeela, P.S., Mohan, V.R. Louis Jesudas, L. and Tresina, P. (2011). Nutritional and antinutritional evaluation of wild yam (*Dioscorea spp.*). Tropical and agroecosystems, 14: 723-730

Shanthakumari, S., Mohan, V.R. and J. De Britto, A. 2008.Nutritional evaluation and elimination of toxic principles in wild yam (*Dioscorea* spp.).Tropical and Subtropical Agroecosystems. 8: 313-319

Sheng, H.W. (2000). Sodium, chloride and potassium. In: Stipanuk M, ed. Biochemical and Physiological Aspects of Human Nutrition. Philadelphia: W.B. Saunders Company; 686-710.

Siddhuraju, P., Becker, K. and, Makkar, H.P.S. (2000). Studies of the nutritional composition andantinutritional factors of three different germplasm seed materials of an underutilized tropical legume, *Mucunapruriens* var. *utilis*. Journal of Agricultural and Chemistry.48: 6048-6060.

Siegeenberg, D., Baynes, R.D.,Bothwell, T.H.,(1991). Ascorbic acid prevents the dose-dependent inhibitor effects of poly phenols and phytates on non hemi iron absorption. American Journal of Clinical Nutrition.

Stone H, and Sidel, J.L. (1993) *Sensory Evaluation Practices*, 2nd ed. San Diego, CA: Academic Press,

Tamiru, M., Heiko, C.B. & Brigitte L.M. (2008).Diversity, distribution and management of yam landraces *(Dioscorea* spp.) in Southern Ethiopia. *Genetic Resourc. Crop Evol.*, 55: 115-131

Thompson, L.U (1993). Potential health benefits and problems associated with antinutrients in foods. Food research introduction 26: 131-149.

Udensi, E.A, Oselebe, H.O., Onuoha, A.U (2010).Antinutritional Assessment of *D. alata* varieties. Pak. J. Nutr. 9(2):179-181.

Ugwu, F.M. (2009). The potentials of roots and tubers as wearing food. Pakistan Journal of Nutrition 8: 1701 -1705.

Vanhonacker, F., Verbeke, W., Lengard, V (2008). Consumer- based definition and general image of traditional foods in Europe. In: *Perspectives of traditional food supply chains on the European Market.* Proceedings of 12th congress of the European Association of Agricultural Economists People, Food and Environments: Global Trends and European Strategies, 26-29 August 2008, Ghent, Belgium.

Vaclavik, V.A., and Elizabeth W. Christian, E. W. (2008). Essentials of Food Science. 3rd ed. Springer Science Business Media, LLC. New York, USA. pp 145-268

Vimala, B. and Nambisa, B. (2005). Tropically minor tuber crops. Central tuber crop research institute, Kerala, India.

Walter ,H.L,. Fanny, L,. Charles, C and Christian, R (2002). Minerals and phytic acid interaction: is it a real problem for human nutrition. Int. J. Food Sc. Tech., 37:727-739.

Wanasundera, J.P.D. and Ravindran, G. (1994). Nutritional assessment of yam (*Dioscorea alata*) tubers. Plant Foods for Human Nutrition46 (1), 33–39.

Whitney, E. and Rolfes, S. R. (2008). *Understanding nutrition* (11th ed.). USA: Thomson Learning Inc.

WHO/FAO (2003). Diet, Nutrition and the prevention of chronic Diseases (PDF), eneva:World Health organization. P 55-56.ISBN 92-4-120916-X.

Appendices

Appendix 1. Questionnaire for Sensory Evaluation of Yam Tubers

Personal information

Code: ________________

Sex: ________________

Age: ________________

Date: ________________

Instruction

You have been provided with three coded samples. Please indicate by ticking the level of response which best describes the attributes of the samples. In other words, examine the samples and indicate how much you like or dislike each based on color, taste, aroma, texture and overall acceptability. Please take water after evaluating each sample to rinse your palates.

Attribute	**Level of Response**						
	Extremely dislike	Dislike	Slightly dislike	Neither like nor dislikes	Slightly like	Like	Extremely like
Color							
Taste							
Aroma							
Texture							
Overall acceptability							

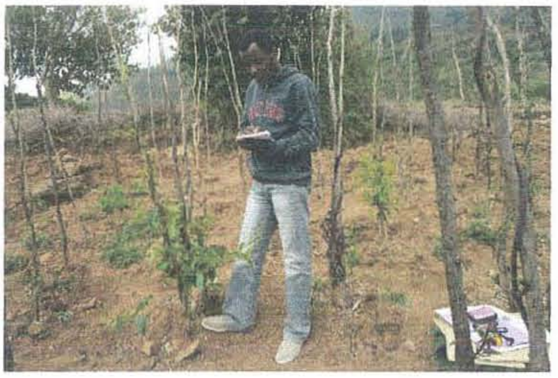
Comment

____

____

____

Appendix2. Photos depicting data collection and specimen collection for yam identification

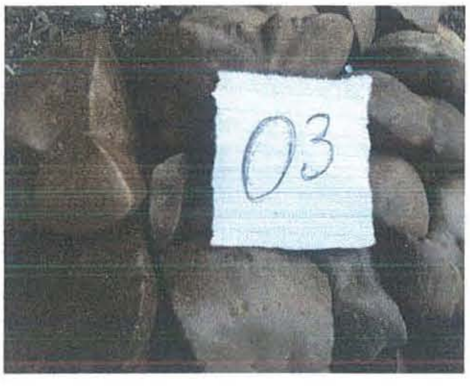


(a) Data collection

(b) Yam plantation in Kucha district

(c) Tubers of *hatiye*

(d) Tuber of *wadala*



(d) Tubers of *bunde-buchi*

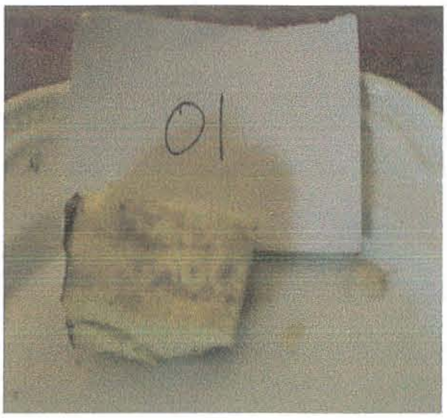
Appendix 2. Photos taken during sensory analysis

(a) Digging out of the yam tubers

(b) Cleaning of the tubers

(c) Washing of the tubers prior to boiling

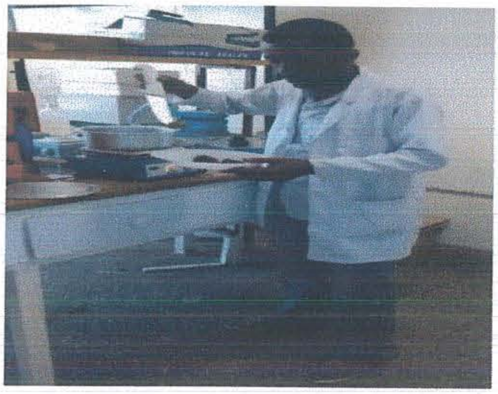
d) Boiling of the yam tubers



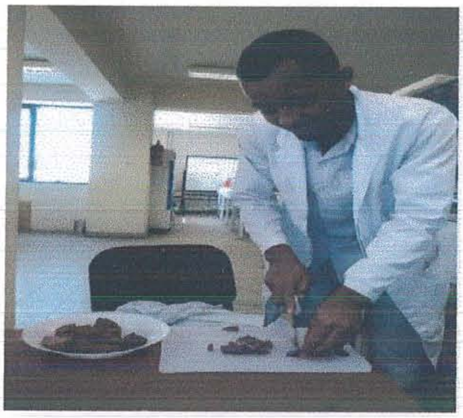
(e) Codding for sensory evaluation

(f) Consumer panelists testing the yam tubers

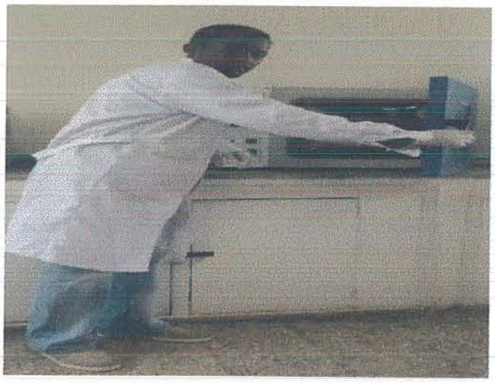
Appendix 3. Photos taken in the laboratory



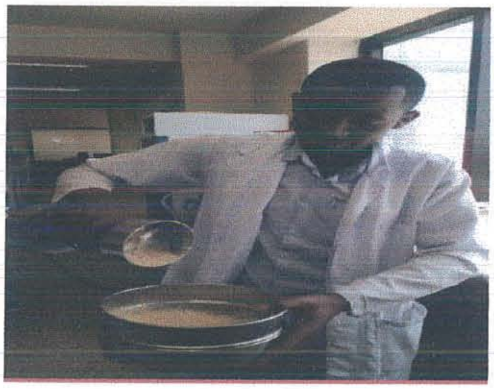
(a) Boiling of the tubers in the laboratory



(b) Slicing of the tubers

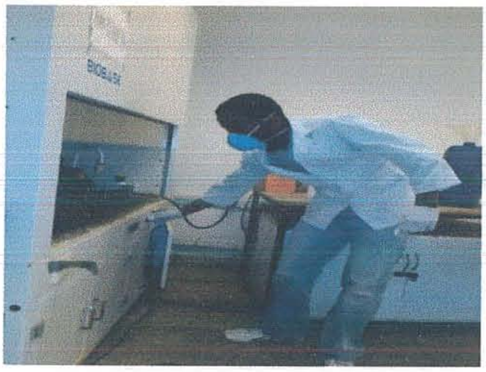


(c) Oven drying of the sliced tubers



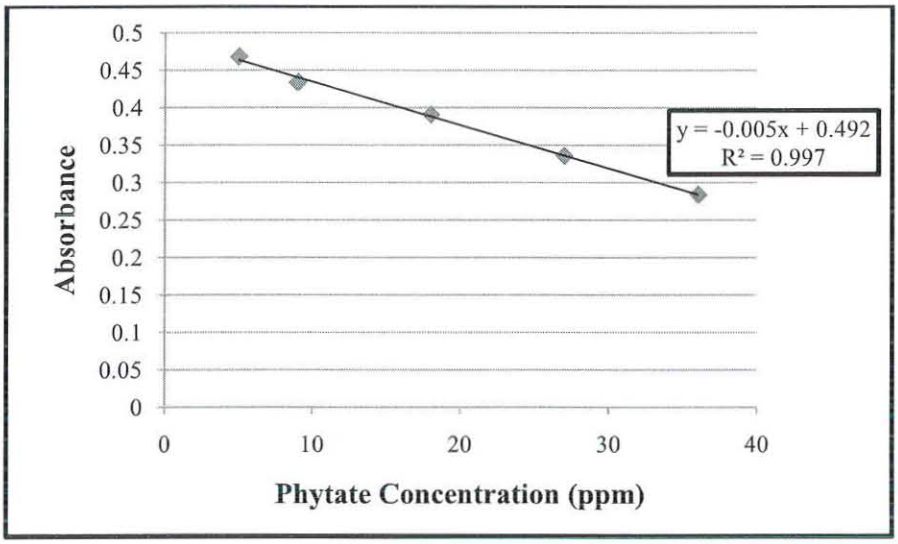
(d) Sieving of the milled yam flour

(e) Packing of the yam flour

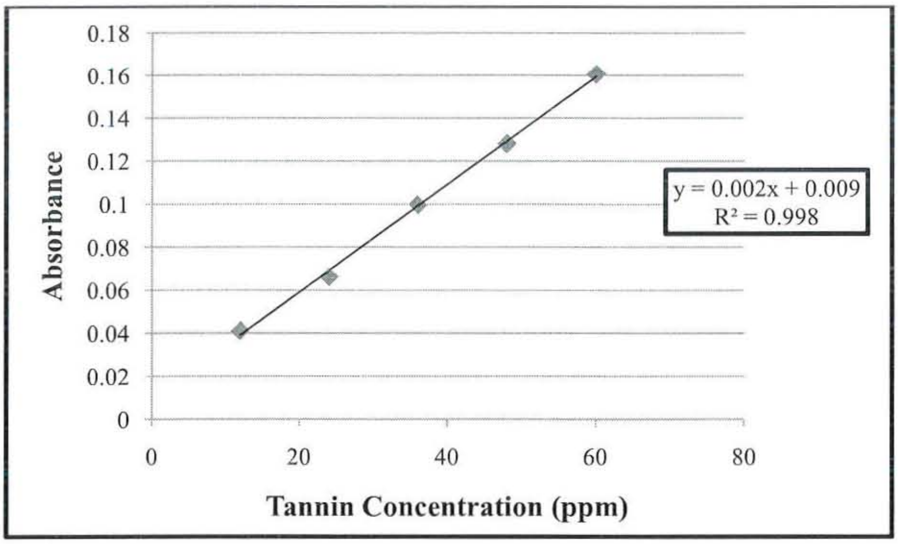


(f) Protein digestion inside Hood

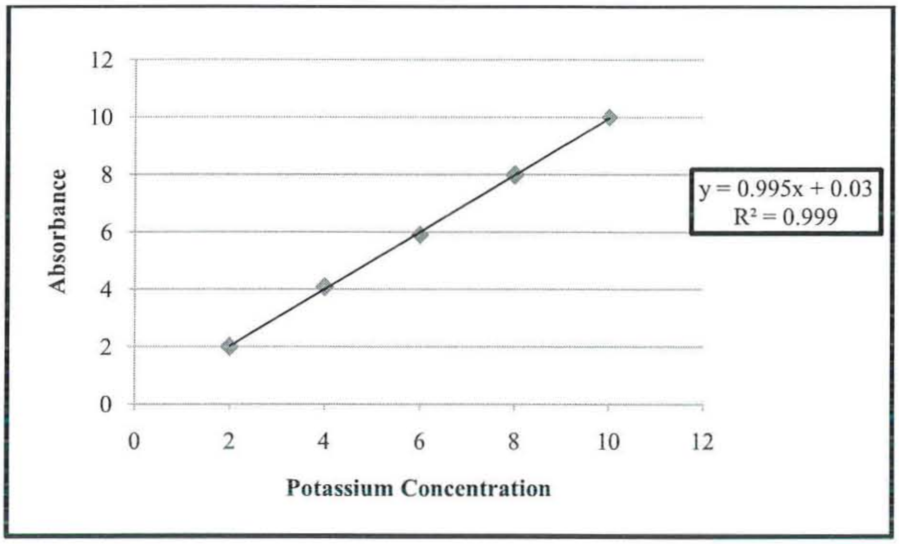
Appendix 4. Calibration curve for phytate



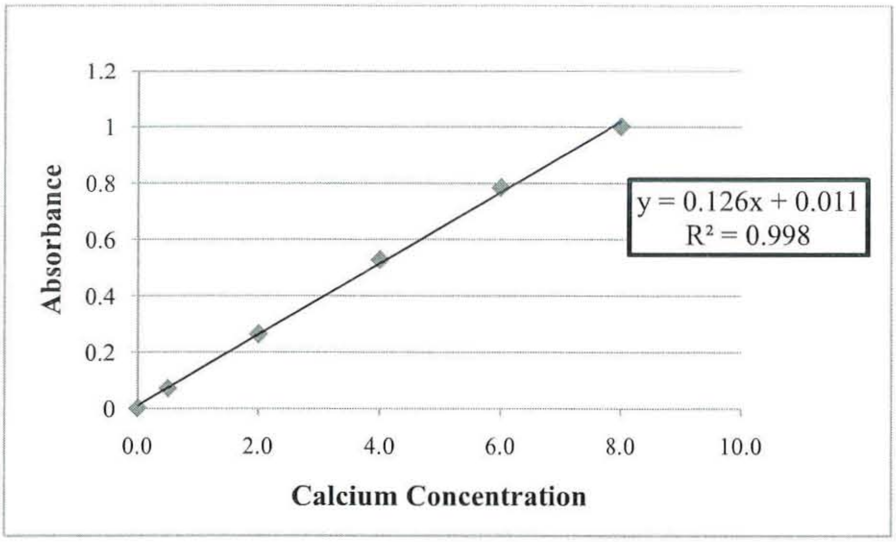
Appendix 5. Calibration curve for Tannin



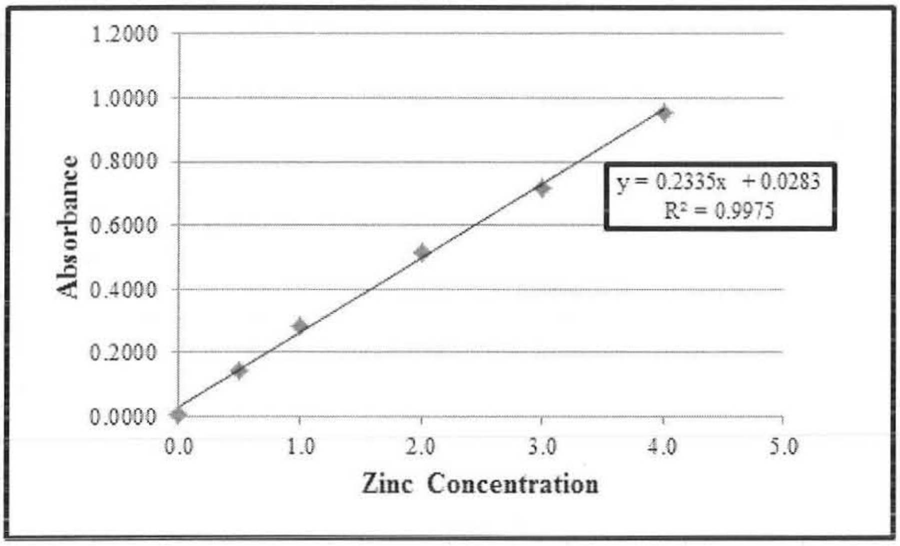
Appendix 6. Calibration curve for Potassium



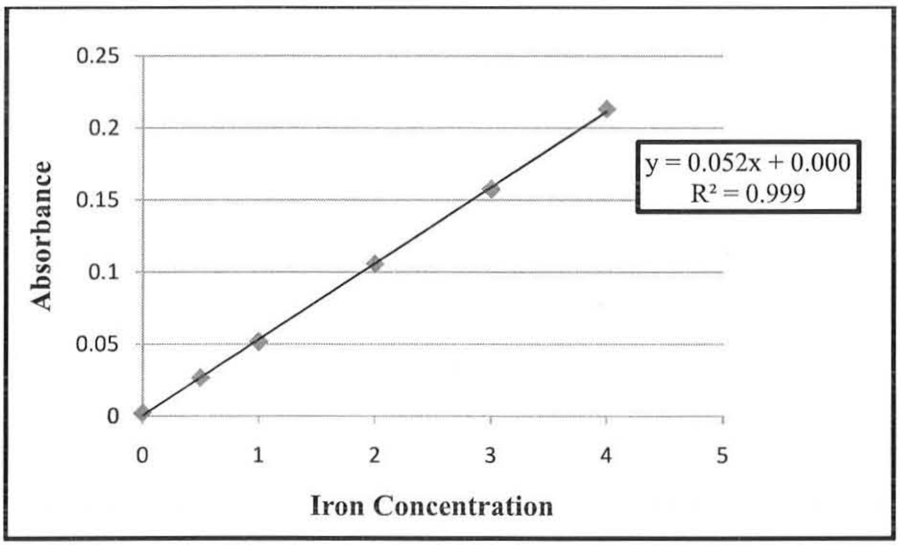
Appendix 7. Calibration curve for Calcium



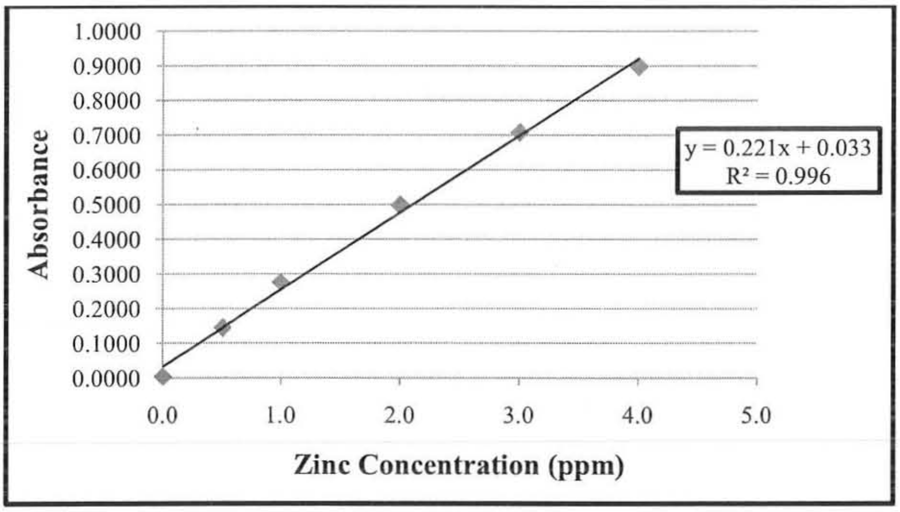
Appendix 8. Calibration curve for Sodium



Appendix 9. Calibration curve for iron



Appendix 10. Calibration curve for Zinc



DECLARATION

I, the undersigned, declare that this thesis is my original work and has not been presented for any degree in this or any other institution and that all sources of materials used in this thesis have been duly acknowledged.

Candidate Name: Fasika Tantu **Signature** ________ 2/07/2015

This thesis has been submitted for examination with my approval as a University advisor. In addition, I declare that this thesis is the original work of my student and has been done under my supervision.

Advisors Name: **Signature**

1. Kelbessa Urga ________ 2/07/2015
2. ________ ________

Approved by the Examining Board:

Name	Signature
1. Getachew Addis	________
2. Dr. Ashagrie Zewdu	________
3. Aynadis Tamene	________
4. ________	________

Place and Date of Submission: Addis Ababa University School of Graduate Studies

Centre for Food Science and Nutrition

Addis Ababa, Ethiopia

June, 2015