Addis Ababa University
College of Natural Sciences
School of Graduate Studies
Center for Food Science and Nutrition

Nutritional and Antinutritional Constituents, and Minerals' Bioavailability of some wild and traditional vegetables of the Gumuz ethnic community, Benishangul Gumuz Regional State

By

Andinet Abera

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.

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Declaration

I, the undersigned, hereby declare that this thesis is my original work and all sources of materials used for the thesis have been correctly acknowledged.

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Dedication

This thesis is dedicated to my late brother Abiyot Abera who passed away while attending the same Masters program with me in the same class room in 2013. My brother how do I say goodbye to a brother that I love as much as you? I still cannot believe you're gone I'm still hoping it isn't true wishing this heartache was just a dream from which I'd wake up and find you still here, in life, with us Or if not...somehow time we could rewind. Abi there's almost no one who shared as much of my life who knows me as well as you. I often think upon the memories we shared when we were very young you teased me, played with me and laughed with me when our lives had just begun. I also dedicate this thesis to my father, dear dad, I would like to THANK YOU for all the things you have done for me since day one. You were always there when there was a problem. You nursed me, raised me, educated me and loved me as much as you were able to with everything that you have been throughout the years, you have made it through. But this battle that you were fighting was a little bit stronger than the strength that you had. I can say for myself and everyone, that I am extremely proud to have you as my FATHER. I LOVE YOU DAD.

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List of acronyms

AAU	Addis Ababa University
ANOVA	Analysis of variance
AOAC	Association of Official Analytical Chemists
CIFOR	Center for International Forestry Research
CE	Catechin equivalent
DM	Dry matter
DRI	Dietary Reference Intakes
EPHI	Ethiopian Public Health Institute
FAO	Food and Agricultural Organization
Fw	Fresh weight
FMHACA	Food, Medicine and Health care Administration and Control Authority
GAE	Gallic acid equivalent
GLV	Green Leafy Vegetables
HPLC	High Performance Liquid Chromatography
LSD	Least Significant Difference
µL	Micro litter
ml	Mili litter
RAE	Retinol activity equivalent
RDA	Recommended Daily Allowance
Rpm	Revolution per minute
SPSS	Statistical Product and Service Solutions
UNICEF	United Nations International Children's Emergency Fund
VAD	Vitamin A Deficiency
WEPs	Wild edible plants
WHO	World Health Organization

1. Introduction

Presently, the world is over dependent on a few plant species and the production of these few plant species may not be enough to feed the rapidly increased population of the world (Bharucha and Pretty, 2010). Promotion of underutilized and neglected but ecologically adapted edible plants could help to ameliorate the problem. Food production must be actively combined with evaluation, selection and domestication, and greater utilization of under-utilized or wild edible plants that are of local or regional importance to effectively increase nutrition security. Diversification of food sources can therefore help to tackle both food and nutritional insecurity. This fact has increased the interest of many researchers on the role of edible wild plants and lesser-known crops in human nutrition (McBurney et al., 2004), many of which are potentially valuable as human and animal food and to maintain a balance between population growth and agricultural productivity, particularly in the tropical and subtropical areas of the world (Gupta et al., 2005).

Various definitions have been given to edible wild plants in literature sources. For the present study, the definition of Gari (2003) was used which stated 'Plants that grow in natural conditions and in some cases include semi-domesticated plants harvested for their human food and nutrition values'.

Wild vegetables play an important role in the diet of inhabitants in different parts of the world (Afolayan and Jimoh, 2009). Numerous wild edible plant species have been used by different communities in Ethiopia, mainly as supplement to conventional foods (Addis et al., 2005; Awas, 2007; Giday et al., 2007; Assefa and Abebe, 2011; Feyssa et al., 2011; Molla et al., 2011; Addis et al., 2013a; Addis et al., 2013b). However, the biodiversity is threatened through replacement of forests with agricultural expansion and deforestation without cultivation and domestication of potential species. These situations could

exacerbate local food shortages and aggravate widespread malnutrition in the country.

Diversification of production and consumption habits to include a broader range of plant species, particularly those currently identified as under-utilized, could significantly contribute to improve health and nutrition, livelihoods and ecological sustainability. Edible wild plants have played an important role in supplementing staple foods by supplying trace elements, vitamins and minerals. (Romojaro et al., 2013). Wild food plants grow in natural conditions; they are easily accessed and freely harvested for their human food and nutrition values. Probably majority of rural households in developing countries rely on forest products to meet some part of their food, nutritional requirement, health and livelihood needs (Sunderland et al., 2011). They are relevant in household food security and nutrition in some rural areas, particularly in drylands, where they represent relevant food sources during seasonal food shortage periods, and provide good nutritional supplies, notably micronutrients (Garí, 2003).

The studies made so far on wild edible plants in Ethiopia provide good indications of the presence of a larger aggregation of plants with edible parts (e.g., fruits, leaves, tubers, seeds) (Addis et al., 2013). Such studies on edible wild plants in different cultures or ethnic communities of the country may contribute to the identification of the most widely used species for further nutritional studies. Nutritional studies provide clues to aid the promotion of those species that have the best nutritional values which helps to ensure dietetic diversity and combat food insecurity (Tardio et al., 2006).

Report on the nutritional content of green vegetables of wild origin shows that they have very higher nutritional potential than some conventional cultivated green vegetables, particularly with respect to their mineral content (Yildirim et al., 2001).

Benishangul-Gumuz region, one of the nine administrative regions of Ethiopia, is endowed with diverse vegetation types upon which communities in the region are highly dependent for their food, medicine and other livelihood uses (Awas, 2007; Giday et al., 2007). However, the region has remained one of the least developed and food insecurity hot spot area. Food shortage is common among the Gumuz people especially during the period of transition to new crop season, i.e. from June-to-September. To cope up with this critical food shortage season, the Gumuz people collect wild vegetables, fruits, and tubers/roots, which appeared to be one of the important local survival strategy (Habtamu et al., 2012). Unpublished assessment on wild edible plants by *Tikuret Le Gumuz Limat Mahiber* has reported more than 200 wild edible plant species (WEPs) and 60 different types of mushrooms are used by the Gumuz community. There is a clear evidence that forest biodiversity makes important contributions to nutrition through the consumption of wild foods from forests and farms providing both a safety net in times of food insecurity and micronutrients, which are often available in a lesser extent from other food sources (Colfer et al., 2006; Vinceti et al., 2008). It is, therefore, worthwhile to note that focus should be provided to study edible wild plants and underutilized vegetables and crops to diversify source of food, which is the most important strategy to reduce the higher prevalence of micronutrient deficiencies, particularly in the communities, and increasing cases of chronic diseases in developing countries. Identification of nutritionally potential edible wild vegetables may help in their domestication and thus supports the present national nutrition strategy that is linking agriculture and nutrition.

Plants are the major sources of micronutrients to the rural populace of the developing countries (Hassan, 2011), including Ethiopia. As the consumption of animal products good in bioavailable minerals is low and plant products low in bioavailable minerals is high in rural communities (Umeta et al., 2005), the

presence of anti-nutritional factors that limits the optimal utilization of wild and semi-wild plants and the extent to which the household food preparation methods could reduces them require investigations. In this thesis, proximate compositions, mineral contents, ascorbic acid, β-carotene contents and antinutritional factors and their effect on bioavailability of Fe, Ca, and Zn in raw and processed young pods of *Abelmoschus esculentus*, tubers of *Dioscorea praehensilis*, aerial part of *Portulaca oleracea* and juvenile shoots of *Oxytenanthera abyssinica* were investigated.

1.1. Statement of the problem

Reduced dietary diversity in sub-Saharan Africa has mainly been attributed to the loss of traditional food systems, particularly as a result of rapid urbanization, estimated to reach over 50% of the total population by 2020 (Bioversity International et al., 2006). Lack of nutritional and agronomic information, a negative attitude towards traditional vegetables termed food for the poor, and absence of policies to promote edible wild and underutilized vegetables and crops are some of the factors that can be mentioned for the reduced dietary diversity and hence micronutrient deficiency.

In most parts of Ethiopia, including Benishangul Gumuz Regional State, edible wild plants and lesser known vegetables forms integral part of the feeding habits, medicine and other livelihoods of rural communities though the frequency of consumption wild edibles is more common in food insecure areas than areas with surplus food sources in the country (Awas and Nordal, 2007; Teklehaymanot and Giday, 2010). Therefore, it is worthwhile to note that the incorporation of edible wild and semi-wild plant resources could be beneficial to nutritionally marginal population or to certain vulnerable groups within population, especially in developing countries where poverty and climatic changes are causing havoc to the rural populace. Despite the wider availability and utilization of edible wild and traditional vegetables in Ethiopia, research on nutrient compositions and their anti-nutrient level as well as the extent of bioavailability of mineral nutrients is not known or lacks adequate attention.

Lack of nutritional information and attention that WEPs are demanding is especially worrying in light of the fact that they are most important to the most vulnerable members of society (Grivetti and Ogle, 2000).

Ethiopian national food consumption survey has recorded wild and less known locally consumed traditional vegetables in Benishangul Gumuz Region by their

local names (proper botanical identification was not done) (EPHI, 2011). However, it was impossible to calculate the contribution of these vegetables to the dietary intake of the individuals because of lack of information on the nutrient composition data of these vegetables. It is therefore essential to conduct nutritional analyses on WEPs in order to assess the quality of existing food as well as to estimate nutrient and mineral intakes contributed from edible wild and cultivated vegetables consumed by the Gumuz community in Benishangul Gumuz region. The nutritional quality of plant food is dependent on the balance between nutritional and metal chelating agents. The present thesis therefore reported nutritional and anti-nutritional compositions, predicted the bioavailability of selected minerals, and determined the retention and losses of nutrients and anti-nutrients following household processing of selected wild and underutilized traditional vegetables of the Gumuz community.

Information obtained from the study result may help to enhance knowledge needed to eradicate the negative attitude towards use and cultivation of the neglected vegetables and is critical in convincing the community and policy makers to assist their promotion for wider consumption and cultivation. It also helps to incorporate nutritional composition of the edible plant parts in the food composition data of the country where the current food composition table totally neglects wild edible plants and locally cultivated traditional vegetables as opposed to their contribution to dietary diversity and agro-biodiversity of the poor in the rural community. Hence, knowledge on nutritional benefits of wild edible and locally cultivated vegetables will assist the nationwide effort to ensure dietary diversity, combat food insecurity, and help to improve the current low fruit and vegetable consumption of Ethiopia which is far below the WHO and FAO recommendations (WHO, 2005).

1. 2. Objectives

1. 2.1. General Objective

The main objective of the present study was to find out the potential of selected vegetables to provide macro and micronutrients to the diets of the Gumuz ethnic community.

1.2.2. Specific Objectives

- To determine the proximate compositions, selected minerals, and vitamins
- To determine anti-nutrients (phytic acid, tannins, total phenols, total alkaloids, cyanides and oxalate) contents in selected indigenous vegetables,
- To predict the bioavailability of selected minerals from selected vegetables, and
- To find out the effect of household processing on nutritional and anti-nutritional compositions of the selected vegetables

2. Literature review

2.1. The concept of wild and traditional vegetables

Edible wild plants refers to species that are neither cultivated nor domesticated, but are available from their wild natural habitat and used as a source of food (Beluhan and Ranogajec, 2011). Whereas, Gari (2003) defined Edible wild plants as 'Plants that grow in natural conditions and in some cases include semi-domesticated plants harvested for their human food and nutrition values'. Wild food plants are relevant in the food security and nutrition of rural people dwelling in arid and semi-arid ecosystems. Traditional vegetables are vegetables that the local species and their varieties are customarily used in agricultural and food systems. These resources are traditional in the sense that they are integrated and coevolving with the indigenous knowledge, agricultural practices, food habits, and cultural dynamics of the rural communities and peoples that hold them. Many traditional vegetables are also considered as minor vegetables due to their little relevance in global agricultural production and trade, as well as to their scant attention in science, rural development programmes, and agricultural policies (Gari, 2003).

2.2. Contribution of edible wild plants in food security

The most widely used definition of food security states that food security exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food which meets their dietary needs and food preferences for an active and healthy life. Household food security is the application of this concept to the family level, with individuals as the focus of concern" (FAO, 2003). This FAO definition of food security includes nutrition security; access to food which ensures adequate macro- and micro- nutrient intake without excessive intakes of calories, fats or refined sugars.

Globally, about 870 million people are estimated to have been undernourished in the period 2010-2012, where developing countries represent 98 percent of this figure (FAO, 2012). Several ethnic communities in Africa use indigenous wild vegetables and fruits to prevent malnutrition and for their medicinal uses (Oladele, 2011). Some part of food, nutritional requirement, health, and livelihoods needs of rural inhabitants in developing countries are met by wild food products from forests and biodiversity (Sunderland et al., 2011). A study in rural South Africa revealed that wild edible vegetables are important source of food, particularly micronutrients, in the maize based subsistence farming sector (Mavengahamaet al., 2013). Similarly, In Zimbabwe, some poor households rely on wild fruits as an alternative to domesticated food sources for a quarter of all the meals in dry seasons [Wilson (1990) as cited in (Neudeck et al., 2012)]. In Ethiopia, above 400 WEPs species have been identified (Molla et al., 2011). The inclusion of indigenous vegetables and fruits (especially where exotic vegetables are not affordable) in the diets is very important in order to alleviate problems of hunger and malnutrition which is most prevalent in several African countries (Oladele, 2011).

The use of indigenous vegetables and fruits is part of African cultural heritage, and they play important role in the tradition and food culture of the African household (Eifediyi et al., 2008). However, use of WEPs is considered by some communities as indicator of poverty and backwardness. This perception is the reflection of lack of knowledge on the nutritional importance of wild and traditional vegetables (Addis et al., 2013).

2.3. Ethnobotanical studies on edible wild plants in Ethiopia

Ethiopia has vast genetic diversity including many wild edible plants used for food, especially during periods of food shortages, with majority of edible parts like leaves, fruits, roots and tubers. However, they are not widely used mainly due to the paucity of information regarding their nutritional value and benefits

(Gelmesa, 2010). For example, in lowland regions of Ethiopia like Afar, *Corchorus olitorous* is collected at young stages and eaten as cooked vegetable. A study carried out in four districts of Ethiopia; Alamata, Cheha, Goma and Yilamana densa, identified one hundred thirty wild edible plant species, from which 152 plant parts are consumed, and the finding revealed that they are used as a source of food both at times of plenty and food shortage times (Addis et al., 2005). An ethnobotanical study on wild edible plants of Konso people, southern Ethiopia, reported that 154 plant parts from 127 plant species are consumed by the community, and wild green leafy vegetables are part of their dishes even though the degree of their consumption is varied due to the seasonal variation, which limits the availability of those vegetables, and level of household food stock (Addis et al., 2013). Thirty wild edible plants species in Bena Tsemay district of south Omo are identified and documented by Assefa and Abebe (2011) of which 15 species have a supplementary role in household food security, three species are used to fill seasonal food shortages and 12 species as emergency role. Balemie and Kebebew (2006) documented the presence of 66 edible plant species belonging to 54 genera and 34 families in Derashe and Kucha districts of southern Ethiopia. Of the reported edibles, 78.8% were reported to be edible both in normal and food shortage times. Similarity, thirty eight wild edible plant species are identified in Kara and Kwego districts of south Omo semi pastoralist areas which are used as food source during the period of both food plenty and scarcity. Though these wild edible plants are used as supplement to the domesticated crops and as famine foods during transition periods to the harvesting season, the nutrient composition and possible toxic effects of many WEPs used in different areas of Ethiopia are not available.

2.4. Edible wild plants and micronutrients

Wild plant species increase the nutritional quality by providing minerals, fiber, vitamins and essential fatty acids and enhance taste and color in rural diets (Yildirim et al., 2001). Underutilized green leafy vegetables are a good source of many nutrients like iron, calcium, ascorbic acid and β-carotene that could help in overcoming micronutrient malnutrition and easily accessed by the community at a low cost. They also had high fiber content and hence would also serve as a source of fiber. Hence, continuous search for new source of nutrient especially from plant foods is a basis for selecting promising species for further studies on GLV to meet the nutritional requirements (Gupta et al., 2005). Evaluation of the nutrient and anti-nutrient compositions of wild edible plants helps to identify foods rich in minerals and acquiring knowledge on the methods of appropriate preparation such as fermentation, soaking and malting, which are known to enhance bioavailability of nutrients (Boukari et al., 2001).

Few studies were carried out to estimate the nutritional values of some wild vegetables used in Ethiopia. Samma leaves (*Urtica simensis* Steudel) reported to have high nutritional value compared to many green leafy vegetables commonly cultivated and consumed in Ethiopia (Getachew et al., 2013). Addis et al. (2013) has also collected 15 most preferred wild edible plants in southern Ethiopia; (*Adenia ellenbeckii, Amaranthus graecizans, Balanites aegyptiaca, Celosia argentea, Coccinia grandis, Corchorus trilocularis, Justicia flava, J. ladanoides, Launaea intybacea, Leptadenia hastata, Pachycymbium laticoronum, Pentarrhinum insipidum, Portulaca quadrifida, Amorphophallus gomboczianus* and *Ximenia caffra*) and analyzed their nutritional values . They found that all green leafy vegetables constituted good amount of mineral nutrients and protein, calcium exceptionally high in *Justica ladanoides* and protein being high in *Coccinia grandis.* Anti nutritional factors are also studied as they cause poor absorption of nutrients and impair health. The role of traditional processing on lowering potential anti nutritional factors needs

to be recognized. Processing green vegetables by boiling water (blanching) was reported to be preferred compared to drying methods to retain carotenoids when the effect was studied on *Coccinia grandis* L Voigt and *Trigonella foenum-graecum* by Addis et al. (2009). Several evidences show that nutritional potential of wild vegetables is very high and is better than some of their domesticated counterparts (Yildirim et al., 2001).

2.5. Overview of the study vegetables

2.5.1. *Abelmoschus esculentus*

Abelmoschus esculentus is commonly known as bhindi in India, krajiab kheaw in Thailand, okra plant, ochro, okoro, quimgombo, quingumbo, gombo, kopi arab, kacang bendi and bhindi in South East Asia (Sorapong, 2012), qenqetse or andeha in Benishangul gumuz of Ethiopia.

It belongs to the family Malvaceae. It probably originated in Ethiopia (Adetuyi et al., 2008; Adetuyi and Osagie, 2011; Sorapong, 2012) but not known for food except by few communities in Benishangul Gumuz. Currently, it grows all over tropical, subtropical and warm temperate regions of the world. However, okra is a commercial vegetable crop with considerable area under cultivation in other parts of Africa and Asia. Its immature fruit plays an important role in the human diet by supplying fats, proteins, carbohydrates, minerals and vitamins (Adetuyi and Adelabu, 2011; Adetuyi and Osagie, 2011; Amin, 2011; Io, 2012; Nwachukwu et al., 2014). Moreover, its mucilage is suitable for certain medicinal and industrial applications (Shah and Seth, 2011). Therefore, young fruits of okra have reawakened beneficial interest in bringing this crop into commercial production.

Adetuyi and Osagie (2011) reported the protein, crude fiber and fat content of different okra varieties within the range of 3.61 - 16.27%, 10.15 - 11.63% and 9.03 -10.57% respectively. Whereas, the mineral content ranges from 1.29-

1.37mg/100g (Zinc); 0.87-0.96mg/100g (Iron); 51.08-51.18mg/100g (Magnesium); 58.22-58.31 mg/100g (Calcium) and 62.05-62.17 mg/100g (Phosphorous) (Adetuyi and Osagie, 2011).

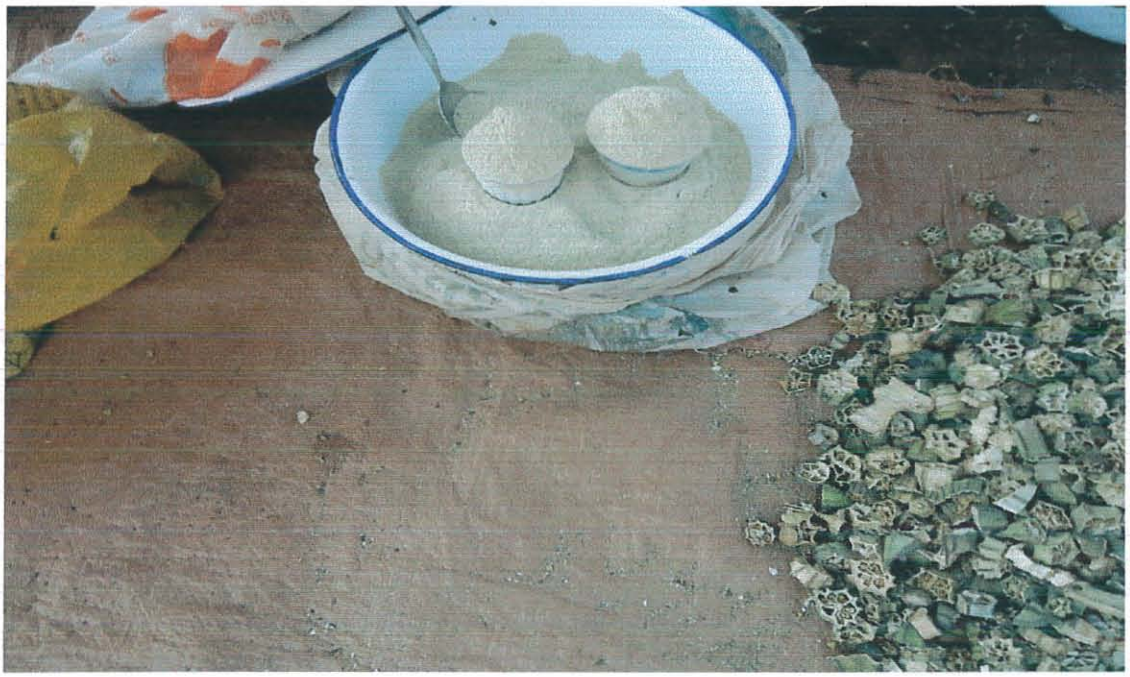


Figure 1: Sundried and powdered young pods of *Abelmoschus esculentus*

2.5.2. *Dioscorea praehensilis*

Yams (Dioscorea) belong to Dioscoreaceae family. They are herbaceous plants with twine and approximately 600 Dioscorea species are eaten as a boiled yam in various parts of the world (Shajeela et al., 2011). *Dioscorea praehensilis* (wild yam) tubers have been considered to be key food to the hunters and gatherers in tropical rainforest of Africa (Sato, 2006). The author found a large community of *D. praehensilis* on the upper part of a small mountain in southern Cameroon. According to the study in Cameroon, the average weight of edible tubers of *D. praehensilis* was reported to range from none to 10.7 kg, with an average of 803 g per stem. The Gumuz community in Benishangul Gumuz region has been using *D. praehensilis* tubers since time unknown (Habtamu et al., 2012).

Figure 2: *Dioscorea praehensilis* benth. tuber

2.5.3. *Portulaca oleracea*

Portulaca oleracea belongs to the family of Portulacaceae. It is commonly known as Purslane in English language and has also many other local names in different regions of the world (Facciola, 1990). It is known as bella in Gumuz and Kawwa in Shinasha. *Portulaca oleracea* is very important because of its medicinal uses, which are attributed to the presence of many biologically active compounds that include flavonoids (Apigenin, kaempferol, quercetin, luteolin, myricetin, genistein, and genistin), Alkaloids, Coumarins, anthraquinone glycoside, cardiac glycoside, high content of ω-3 fatty acids and β-carotenes (Rasheed et al., 2004). It is a rich source of omega-3-fatty acids, which is important in preventing heart attacks and strengthening the immune system. Aerial part of the plant has also been traditionally used as vegetable (Tan et al., 2013). Purslane (*Portulaca oleracea* L.) is a rich source of important nutrients such as minerals and antioxidants. In addition, raw leaves, stems and buds have been reported to contain high levels of oxalate and, therefore, they are not

recommended for regular consumption for people who have a tendency to form kidney stones (Poeydomenge and Savage, 2007).

Figure 3: *Portulaca oleracea*

The leaves and stems of porulane grown in Iran were studied by Aberoumand (2008) and reported the total ashes (22.66%), crude protein (3.47%), crude lipid (5.26%), crude fiber (8.0%) and carbohydrates (40.67%).

The fatty acid and β-carotene contents of the Australian varieties of P. oleracea were found to be in the range of 1.5 to 2.5 mg/g of fresh mass in leaves, 0.6 to 0.9 mg/g in stems and 80 to 170 mg/g in seeds. The β-carotene content ranged from 22-to-30 mg/g fresh mass in leaves (Rashed, 2004).

The shinasha and Gumuz people have long history of using the fresh leaves and steams of P. oleracea as a raw vegetable sauce along with porridge and traditional thick fermented bread made from the flour of finger millet, maize, sorghum or their mixture known as chimbo or beddo.

2.5.4. *Oxytenanthera abyssinica*

Ethiopia as a whole has about 1 million hectares of bamboo from which 850,000 hectares are lowland and 350,000 hectares are highland bamboo. From this figure, Benishangul-Gumuz has 440, 000 hectares of Shimal bamboo (*Oxytenanthera abyssinica*) which at present is mainly used for subsistence uses such as housing, fencing, kitchen utensils, and agricultural implements and shoots for food (International Network for Bamboo and Rattan, 2010). The Gumuz community has a long history of using *O. abyssinica* young shoots as food, house construction and manufacturing household utensils (Habtamu et al., 2012).

Bamboos provide food, shelter, medicine, raw materials for construction, wood substitute, and paper and pulp for industry. They are also used for making furniture, handicrafts, containers and many other utensils used in a day to day life particularly for the rural community. The juvenile shoots are not only delicious but are rich in nutrient components, mainly proteins, carbohydrates, minerals (mainly potassium), and fiber and are low in fat and sugars.

In addition, it contains phytosterols that can be labeled as nutraceuticals or natural medicines that are attracting the attention of health advocates and scientists alike (Chongtham et al., 2011). Research findings revealed that bamboo shoots have a number of health benefits that help in improving appetite and digestion, losing weight, and curing cardiovascular diseases and cancer.

Despite the wide distribution and traditional use of *O. abyssinica* in Ethiopia, there is no information on the ethnobotanical and nutritional study on this important indigenous plant so far.

Table 1: Estimated bamboo shoot annual import/export statistics for major countries.*

	Import (tons)		Export (tones)	
Country	Canned	Fresh/frozen	Canned	Fresh
Australia	12000	-	-	-
Japan	130000	4000	-	-
USA	44000	-	-	-
Taiwan	5000	-	385	1500
China	-	-	143000	7000
Thailand	-	-	68000	-
Others	99000	6000	40500	1500
Total	290000	10000	290000	10000

*source (ERG, 2004)

Bamboo shoots (BSs) are consumed as cooked, dried, fermented, pickled, and in shredded form (Choudhury et al., 2010). In addition to essential nutrient components, bamboo shoots contain potentially toxic cyanoglycoside, called taxiphyllin, which is turned on by the hydrolytic enzyme: β-glycosidase, upon disruption of the plant cell. Taxiphyllin further breaks down into cyanohydrin and sugar, which rapidly decomposes into hydrocyanic acid and an aldehyde or a ketone (Choudhury et al., 2012)

Figure 4: The low land bamboo shoots (*Oxytenanthera abyssinica*)

2.6. Micronutrients: Benefits and availability in vegetables

Micronutrients are vitamins and minerals needed by the body in small amounts for a wide range of functions and processes essential for optimal human growth and development, and healthy maintenance of the body over a life span (Ruel, 2001). Micronutrient deficiencies affect billions of people globally. Although less prevalent in higher-income populations, these deficiencies do occur in such groups, especially among premature infants, children, and the elderly. Several sources revealed that plant foods provide micronutrients to human beings (e.g. vitamin C, E, foliate, and Vitamin A precursors; minerals such as: Fe, Zn, Cu, Ca, Na, K, P, Se, Mn, and Mg) (Jacob, 1998; Goldberg, 2003; Ekesa et al., 2012).

The body of humans and animals requires seven minerals in a relatively large (gram) amount (i.e. calcium, sodium, magnesium, potassium, phosphorus, chlorine, and sulphur), and at least seven in trace amounts (cobalt, copper, iodine, iron, manganese, molybdenum, and zinc) (Osborne and Voogt, 1978). Minerals are involved in the control of body fluids, in the building of rigid structures to support the body, in chemical reaction in the body, and as chemical constituents of the body. Minerals are also important co factors of money enzymes and coenzymes in the body.

Because micronutrient deficiencies (such as vitamin A) are associated with low intake of foods such as vegetables, as opposed to starchy (energy rich) staples which provide the majority of energy intake in typical African diets (Stephenson et al., 2010), increment in energy production and consumption will likely do little to ameliorate the problem of micronutrient deficiency. In fact, increased availability of energy rich, but micronutrient poor foods (such as staples) may simply add to the growing obesity epidemic in developing country populations (even amongst the poorest and most food insecure populations). Increased vegetable consumption is an essential component of achieving food security and

good nutrition in Africa. According to WHO (2005), vegetable intake in 10 sub-Sahara African countries ranges from 19.6 to 88.3 kg / capita / year, and that all countries fell far below the WHO/FAO recommendation for fruit and vegetable intake of 146kg/capita/year. Important vitamins and minerals, including Vitamin A and iron come largely from vegetables in typical African diets (WHO, 2005).

2.6.1. Iron

Iron has several vital functions in the body. It serves as a carrier of oxygen to the tissues from the lungs by red blood cells, haemoglobin as a transport medium for electrons within cells, and as an integrated part of important enzyme systems in various tissues (FAO/WHO, 2001).

Most of the iron in the body is present in the erythrocytes as haemoglobin, a molecule composed of four units, each containing one haem group and one protein chain (Mascotti, 1995). The structure of haemoglobin allows it to be fully loaded with oxygen in the lungs and partially unloaded in the tissues. The iron-containing oxygen storage protein in the muscles, myoglobin, is similar in structure to haemoglobin but has only one haem unit and one globin chain (Dallman, 1986).

Iron plays a greater role in the normal growth and functioning of human physiology. A technical report on human vitamin and minerals requirement states that the requirements for absorbed iron in infants and children are very high in relation to their energy requirements and infants have no iron stores and have to rely on dietary iron lone. Iron deficiency is the most prevalent nutritional deficiency around the world; affecting children from poor communities. Populations most at risk for iron deficiency are infants, children, adolescents, and women of childbearing age, especially pregnant women (FAO/WHO, 2001). The prevalence of iron deficiency is not yet documented in Ethiopia. It is possible to

meet high requirements of iron if the diet has a consistently high content of meat and foods rich in iron and ascorbic acid such as dark green leafy vegetables.

2.6.2. Zinc

Zinc is an essential component of a large number (>300) of enzymes participating in the synthesis and degradation of carbohydrates, lipids, proteins, and nucleic acids as well as in the metabolism of other micronutrients. Zinc stabilizes the molecular structure of cellular components and membranes and in this way contributes to the maintenance of cell and organ integrity. Furthermore, zinc has an essential role in polynucleotide transcription and thus in the process of genetic expression. Its involvement in such fundamental activities probably accounts for the essentiality of zinc for all life forms. Zinc plays a central role in the immune system, affecting a number of aspects of cellular and humoral immunity (Shankar and Prasad, 1998).

The clinical features of severe zinc deficiency in humans are growth retardation, delayed sexual and bone maturation, skin lesions, diarrhoea, alopecia, impaired appetite, increased susceptibility to infections mediated via defects in the immune system, and the appearance of behavioral changes (Hambridge, 1987).

A study conducted by Umeta et al. (2000) showed the presence of zinc deficiency in Ethiopia. In their intervention study, it was found that combating zinc deficiency can increase the growth rate of stunted children to that of non-stunted children in rural Ethiopia and called for the need for zinc supplementation.

Lean red meat, whole-grain cereals, pulses, and legumes provide the highest concentrations of zinc; concentrations in such foods are generally in the range of 25–50mg/kg (380–760mmol/kg) raw weight. The utilization of zinc depends on the overall composition of the diet (Gibson et al., 2007). Experimental studies have identified a number of dietary factors as potential promoters or antagonists of zinc absorption. Soluble organic substances of low relative molecular mass,

such as amino and hydroxy acids, facilitate zinc absorption. In contrast, organic compounds forming stable and poorly soluble complexes with zinc can impair absorption. In addition, competitive interactions between zinc and other ions with similar physicochemical properties can affect the uptake and intestinal absorption of zinc (FAO/WHO, 2001).

2.6.3. Calcium

Calcium is a divalent cation with an atomic weight of 40. In the elementary composition of the human body, it ranks fifth after oxygen, carbon, hydrogen, and nitrogen, and it makes up 1.9% of the body by weight. Nearly all (99%) of total body calcium is located in the skeleton. The remaining 1% is equally distributed between the teeth and soft tissues, with only 0.1% in the extracellular fluid (Robertson, 1981). Calcium salts provide rigidity to the skeleton and calcium ions play a role in many metabolic processes.

There is no data regarding the calcium status of population in Ethiopia. But the national food consumption survey has estimated low calcium intake particularly in the rural population.

2.6.4. Phosphorous

Phosphorus is a component of membrane phospholipids, nucleotides and nucleic acids, and a component of bones and teeth (Whitney and Rolfes, 2008). It functions to buffer body fluids to maintain a normal pH, to temporarily store and transfer energy derived from metabolic fuels, and to activate many catalytic proteins through phosphorylation. Phosphorus is so widely distributed in foods that deficiency is produced only in near starvation or in re-feeding of depleted individuals without adequate attention to supplying phosphorus (Dickinson, 2002).

2.6.5. Copper

Copper is a component of a number of enzymes that are involved in reducing molecular oxygen. Copper is part of numerous enzymes involved in metabolizing substances such as histamine, serotonin, epinephrine, norepinephrine, and dopamine. Copper is a component of enzymes that oxidize ferrous iron and facilitate the binding of iron to transferrin, and is also part of cytochrome c oxidase, a critical component of energy production. Copper deficiency is rare but results in a hypochromic anemia. Deficiency may also reduce bone density (Dickinson, 2002).

2.6.6. Potassium

The mineral potassium is the main intracellular cation in the body and is required for normal cellular function (Whitney and Rolfes, 2008). The ratio of extracellular to intracellular potassium affects nerve transmission, muscle contraction, and vascular tone.

Fruits and vegetables, particularly leafy greens, vine fruit, and root vegetables, are good food sources of potassium. Although uncommon in the general population, the main effect of severe potassium deficiency is hypokalemia (Otten et al., 2006). Hypokalemia can cause cardiac arrhythmias, muscle weakness, and glucose intolerance. Moderate potassium deficiency, which typically occurs without hypokalemia, is characterized by elevated blood pressure, increased salt sensitivity, an increased risk of kidney stones, and increased bone turnover. An inadequate intake of potassium may also increase the risk of cardiovascular disease, particularly stroke.

2.6.7. Vitamin A

Globally, one in three preschool-aged children and one in six pregnant women are deficient in vitamin A due to inadequate dietary intake, the highest prevalence being recorded in Africa and South East Asia (UNICEF, 2013). The prevalence of vitamin A deficiency (VAD) in developing countries among young

children alone is estimated to be 30%. Yet, Food-based approaches to combating vitamin A deficiency continue to be largely ignored by governments and donors (United Nations System Standing Committee on Nutrition, 2010). A wide variety of common and indigenous foods are proven effective in improving vitamin A status even in short-term trials (Prakasam et al., 2002). To the contrary, supplementation approach, which monopolize the attention for decades, fails to improve vitamin A status and is even lacking in proof of impact on young child mortality in real life settings (Greiner, 2013). Because of humans lack the ability to synthesize vitamin A, we depend on the dietary intake to meet our physiological needs. Furthermore, if our habitual diet provides too little bioavailable vitamin A, some health problems related to vitamin A-deficiency can be suffered (Watson, 2001). The most specific clinical effect of inadequate vitamin A intake is xerophthalmia, which is estimated to affect 3 million to 10 million children (mostly in developing countries) annually. Of those affected, 250,000 to 300,000 go blind every year. Xerophthalmia is an irreversible drying of the conjunctiva and cornea. Various stages of the disease include night blindness (impaired dark adaptation due to the slowed regeneration of rhodopsin), conjunctival xerosis, Bitot's spots, corneal xerosis, corneal ulceration, and scarring, all related to vitamin A deficiency (Otten et al., 2006).

Vitamin A plays a fundamental role in supporting growth, reproduction, and embryonic development, as well as in regulating cell differentiation and proliferation, and maintains an important function in the immune system. Retinoids are required in the process of vision, since retinal is involved as a chromophore in phototransduction (Kim, 2002). The parent compound vitamin A, found only in fats of animal origin, is known as retinol and is an unsaturated monohydric alcohol. Retinol is not found in plants but is present as precursors (or provitamins) in the form of carotenoids, which are converted into retinol *in vivo*. Of the approximately 600 carotenoids found in nature, only three are

important precursors of vitamin A in humans: α-carotene, β-carotene and β-cryptoxanthin (Watson, 2001). β-carotene is the most abundant in carotenoid-containing foods, and since its vitamin A potency is greater than that of other carotenoids (Osborne & Voogt, 1978), it is regarded as by far the most important nutritionally.

Preformed vitamin A is found almost exclusively in animal products, such as human milk, glandular meats, liver and fish liver oils (especially), egg yolk, and whole milk and dairy products. Pro-vitamin A carotenoids are found in green leafy vegetables (e.g., spinach, amaranth, and young leaves from various sources), yellow vegetables (e.g., pumpkins, squash, and carrots), and yellow and orange non citrus fruits (e.g., mangoes, apricots, and papaya) (FAO/WHO, 2001).

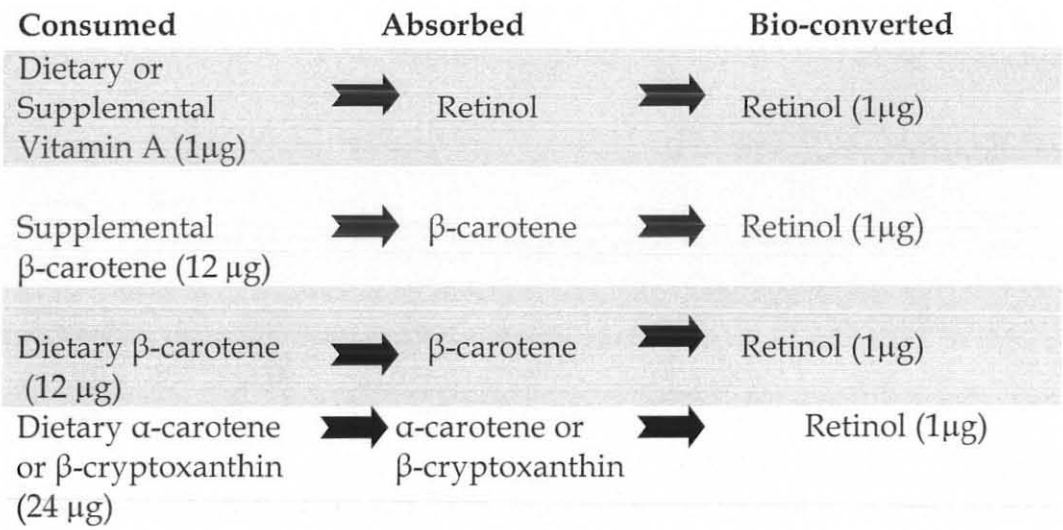


Figure 5: Absorption and bioconversion of ingested provitamin A carotenoids to retinol based on new retinol equivalency ratio (Otten et al., 2006)

Bioavailability of vitamin A to the body appeared to be influenced by factors such as dietary fat intake, intestinal infections, the food matrix, and food processing (Reference). Dietary fat enhances absorption, whereas absorption is diminished in individuals with diarrhea, intestinal infections, and infestations (Greiner, 2013).

2.6.8. Vitamin C

Vitamin C (ascorbic acid or ascorbate) is a six-carbon lactone which is synthesized from glucose by many animals. Vitamin C is synthesized in the liver in some mammals and in the kidney in birds and reptiles. However, several species including humans and non-human primates are unable to synthesize vitamin C (FAO/WHO, 2001). When there is insufficient vitamin C in the diet, humans suffer from the potentially lethal deficiency disease, scurvy.

Vitamin C is an electron donor (reducing agent or antioxidant) and it acts as an electron donor for 8 human enzymes (Levine, 1986; Englard and Seifter, 1986). Vitamin C promotes absorption of soluble non-haem iron (Gillooly et al., 1983), possibly by chelating or simply by maintaining the iron in the reduced (Fe2+) form. The effect can be achieved with the amounts of vitamin C obtained in foods. However, the amount of dietary vitamin C required to increase iron absorption ranges from 25 mg upwards and depends largely on the amount of inhibitors, such as phytates and polyphenols, present in the meal (Hallberg, 1987).

Ascorbate is found in many fruits and vegetables. Citrus fruits and juices are particularly rich sources of vitamin C but other fruits including, cherries, mangoes, papaya, strawberries, watermelon, and tomatoes also contain variable amounts of vitamin C. Vegetables such as cabbage, broccoli, Brussels sprouts, bean sprouts, cauliflower, kale, mustard greens, red and green peppers, peas, tomatoes, and potatoes may be more important sources of vitamin C than fruits. This is particularly true because the vegetable supply often extends for longer periods during the year than does the fruit supply (FAO/WHO, 2001). All the vegetables associated with moderate or good Fe bioavailability contained appreciable amounts of one or more of the organic acids, malic, citric and ascorbic acids (Gillooly et al., 1983). Generally, Vitamin C is an important water soluble antioxidant and plays a significant role in maintaining the preferred

oxidation-reduction potential in human tissues (Prakash et al., 1995) and vegetables and fruits constitute an inexpensive and rich source of this important nutrient (Aberoumand, 2009).

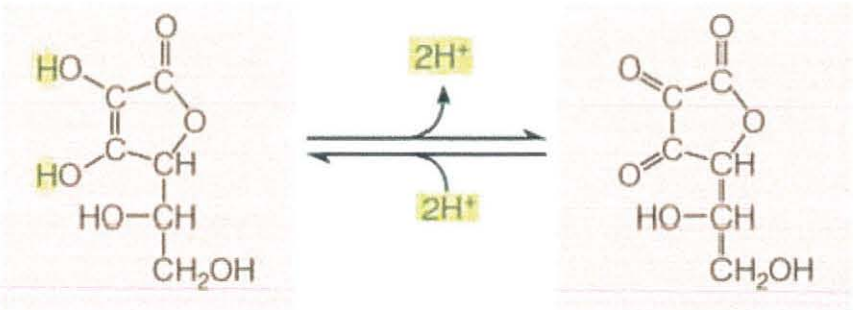


Figure 6: Active forms of vitamin C (the two hydrogens highlighted in yellow gives vitamin C its acidity and its ability to act as an antioxidant) (Whitney and Rolfes, 2008)

2.7. Antinutritional factors in plant foods

Anti-nutritional factors are those substances found in most food substances which are poisonous to humans or in some ways limit the nutrient availability to the body (Inuwa et al., 2011). Plants evolved these substances to protect themselves and because they are very essential for biological functioning of plants. The presence of anti-nutrients such as phytate, tannin, oxalate, and polyphenols in the food may affect the extent of bioavailability of the minerals in the body (Gillooly et al., 1983), when ingested by human, these compounds reduce the bioavailability of minerals and digestibility and absorption of other nutrients. The bioavailability of nutrient from plant foods is dependent on several dietary factors when they are consumed, including: (1) the chemical form of nutrient in the food and the nature of the food marix; (2) formation of complex insoluble compounds by the interactions between nutrients and other organic compounds within the plant foods; (3) the preparation practices or pretreatment of plant foods (Gibson et al., 2007). Chemical substances present in foods and

reported to have some level of toxicity in mankind includes aflatoxin, oxalates, alkaloids, acrylamide, pytic acid, saponin, tannins, and cyanogenic glycosides (Adeniyi et al., 2009).

2.7.1. Oxalates

Oxalates belongs to a group of molecules called organic acids, and is routinely synthesized by plants and animals (Dash and Gurumoorthi, 2011). The physiological system of humans uses vitamin C to produce oxalates. In addition oxalate reaches our body system from dietary sources which are recognized as inhibitors of mineral bioavialbiliy and also results in extreme pain when deposited in vital organs of the body. The amount of oxalate ingested may be an important risk factor for the development of idiophatic calcium oxalate nephrolithiasis (Holmes and Kennedy, 2000). The main soruces of dietary oxalates are plants and plant products mainly seeds and leafy vegetables in a readily water-soluble form as potassium, sodium and ammonium oxalates and as insoluble oxalates such as calcium oxalate. Animal products have neglible oxalate content. Oxalate forms strong chelates with dietary calcium, thus rendering the complex unavailable for absorption and assimilation. It precipitates as insoluble salts accumulating in the renal glomeruli, and contributes to the development of renal disorder (Judprasong et al., 2006).

2.7.2. Phytate

Phytic acid is hexaphosphate ester of inositol. Phytates are the primary storage form of both phosphate and inositol in plant seeds and grains (Gargari et al., 2007). High phytate content is recognized to be the inhibitor of mineral bioavailability most notably zinc and iron from vegetables as well as cereal foods (Hurrell et al., 2003). Phytic acid exerts its inhibitory effect on the absorption of zinc and iron by forming insoluble complexes in the gut under physiological condition (Wise, 1995). The formation of such chelates depends on the ratio of the content of zinc, iron or calcium relative to that of phytate in the food (Morris and

Ellis, 1989). Other minerals of nutritional importance that are chelated by phytate are copper and manganese (Umeta et al., 2005).

2.7.3. Total polyphenols

Phenolic compounds are substances that possess an aromatic ring bearing a hydroxyl substituent, including their functional derivatives such as esters, methoxy compounds and glycosides (Kim et al., 2005). The term phenolics encompasses approximately 8000 naturally occurring compounds, all of which possess one common structural feature, a phenol (an aromatic ring bearing at least one hydroxyl substituent) (Bravo, 1998). Current classification divides the broad category of phenolic compounds into polyphenols and simple phenolics, based solely on the number of phenol subunits present. Polyphenols possessing at least two phenol subunits include the flavonoids, and those compounds possessing three or more phenol subunits are referred to as the tannins (hydrolyzable and non-hydrolyzable) (Robbins, 2003).

According to the study by Gillooly et al. (1983), when the total polyphenol content in all the vegetables tested was formally measured, there was a significant inverse correlation with Fe absorption. He founded that a number of vegetables associated with low Fe absorption turned bluish-black when Fe was added to them, suggesting that the total polyphenol content in them was high.

On the other hand, Phenolics behave as antioxidants, due to the reactivity of the phenol moiety (hydroxyl substituent) on the aromatic ring (Lesschaeve and Noble, 2005; Manach et al., 2005; Scalbert et al., 2005). Although there are several mechanisms, the predominant mode of antioxidant activity is believed to be radical scavenging via hydrogen atom donation (Robbins, 2003). Though polyphenols initially were identified for their antioxidant property, many of these compounds exhibited a wide range of biological activities, such as antifungal, antibacterial, antiviral and therapeutic properties (Keser et al., 2013).

The health benefit effects of plant foods derive from its content not only in micronutrients, but also in polyphenols (Pinto et al., 2013). These plant secondary metabolites include flavonoids, phenolic acids, lignans, coumarins, phenols, phenylpropanoids, quinones, stilbenoids and xanthones (Scalbert et al., 2005).

2.7.4. Tannins

Tannins are compounds of intermediate to high molecular weight with a molecular mass of up to 30,000 Da. Tannins can form insoluble complexes with carbohydrates and protein (Bravo, 1998). Plant tannins can be subdivided into two major groups: (1) hydrolysable and (2) condensed tannins. Gillooly et al. (1983) reported that there was a marked inhibition of the geometric mean absorption of iron when 500 gram tannic acid was added to green leafy vegetables.

2.7.5. Cyanogenic glycosides

Cyanogenic glycosides yield hydrogen cyanide upon hydrolysis and thus toxic at a certain concentrations (Monago and Akhidue, 2002). The key characteristic of these toxins is cyanogenesis, the formation of free hydrogen cyanide, and is associated with cyanohydrins that have been stabilized by glycosylation (attachment of sugars) to form the cyanogenic glycosides. It is also a known inhibition of respiratory chain, inhibiting the metalloenzymes which may result in the deficiency of oxygen to the tissues and thus may lead to death (New Zealand Food Safety Authority, 2013). The cyanide anion is an inhibitor of the enzyme cytochromec oxidase (a trans-membrane protein complex found in mitochondria and bacteria), attaching to the iron within this protein and preventing the transport of electrons from the enzyme to oxygen. Consequently, the eukaryotic cell can no longer aerobically produce ATP for energy and cellular respiration is greatly reduced, affecting those tissues most dependent on, especially the central nervous system and the heart (Saunders, 2012).

2.7.6. Alkaloids

Alkaloids are chemically varied group of plant constitutes containing a basic nitrogen being common for the various classes. They contain one or more nitrogen atoms usually in a heterocyclic ring and have a marked physiological action on man or other animals. Most alkaloids are well-defined crystalline substances that unite with acids to form salts. Knowledge of the solubility of alkaloids and their salts is of considerable pharmaceutical importance. Although these alkaloids have at present great medicinal significance, they are important in that they constitute the poisonous hepatotoxic constituents. Some of the alkaloids also show carcinogenic and mutagenic properties and have caused concern in that they occur in small quantities in some herbal products (Evans, 1997).

2.8. Effect of processing on nutrients and antinutrients

Several traditional household processing methods can affect the bioavailability of nutrients in plant-based diet (Akin-Idowu et al., 2009). These include thermal processing, mechanical processing, soaking, fermentation and germination (Gibson et al., 2007; Nestares et al., 2003).

Food of plant origin contains many bioactive compounds and thus serves as an important source of minerals, vitamins and certain hormone precursors in addition to protein and energy sources (Goldberg and British Nutrition Foundation, 2002). However, the presence of inherent toxic factors or antinutritional components in plants has been one major obstacle in harnessing the full benefits of nutritional value of plants foods (Gibson et al., 2007), vegetable inclusive. However cooking and blanching have been highlighted as possible means of reducing the antinutrient levels in plant food sources to innocuous level that can be tolerated by monogastric animal including man (Addis et al., 2009; Ilelaboye et al., 2013). Toxic compounds in plant foods consist of some flavonoids, alkaloids, tannins, cyanogenic compounds, phytate and

trypsin inhibitors. For human consumption the different vegetables are processed by various methods which include soaking, boiling, sprouting, pressure cooking and fermentation depending upon tradition and taste preferences. These processing treatments are also effective in eliminating the antinutritional factors (Kakati et al., 2010; Karkle and Beleia, 2010).

To our knowledge, there is no report on nutrient compositions, toxic and antinutritional constituents, and the effect of household processing methods of *Abelmoschus esculentus*, *Dioscorea praehensilis*, *Oxytenanthera abyssinica* and *Portulaca oleracea* grown in Ethiopia.

3. Materials and methods

3.1. Selection of vegetable species

Selection of species for our investigation was based on ethnobotanical study findings in the study area (Awas, 2007; Habtamu et al., 2012); *Dioscorea praehensilis* Benth (tuber), *Oxytenanthera abyssinica* Munro (young shoot), *Abelmoschus esculentus* (L.) Moench (immature pod) and *Portulaca oleracea* L. (aerial part) were selected based on their wider utilization by the community in the study area. The first two vegetables are wild and the last two exist both under cultivation and wild stand. The selected vegetables were recommended for domestication according to an association in Benishangul Gumuz called *"Tikuret le Gumuz Limat Mahiber'* for the reason that they are widely consumed by the community and because they are most suited for domestication. Each species were collected at the time when edible parts are acceptable for consumption by the local community. Voucher specimens of the selected edible plants were collected and processed for verification. The specimens were identified by a botanist from Bioversity International and Ethiopian Public Health Institute (EPHI) using standard procedures, and deposited in the National Herbarium of Addis Ababa University (AAU) and EPHI.

3.2. Sample collection

Edible parts of the selected vegetables were harvested manually from their natural habitat in different areas of Agalometi woreda. Five kilograms of edible part of the respective species were collected from 20 different plants of the same species to ensure the representativeness. The plant materials were placed in ice box and transported to Ethiopian Public Health Institute in Addis Ababa.

Agalo Meti is one of the woredas in the Kemash zone of Benishangul Gumuz Regional state located at 530 km west of Addis Ababa with altitudes ranging from about 1000 to 2500 meters above sea level.

Household processing methods of vegetables for consumption

Methods of preparing vegetables for consumption by the local community were studied using semi-structured questionnaire (Annex, 6). Twenty households were visited and females of 18 and above years old interviewed on preparation of each of the selected vegetables.

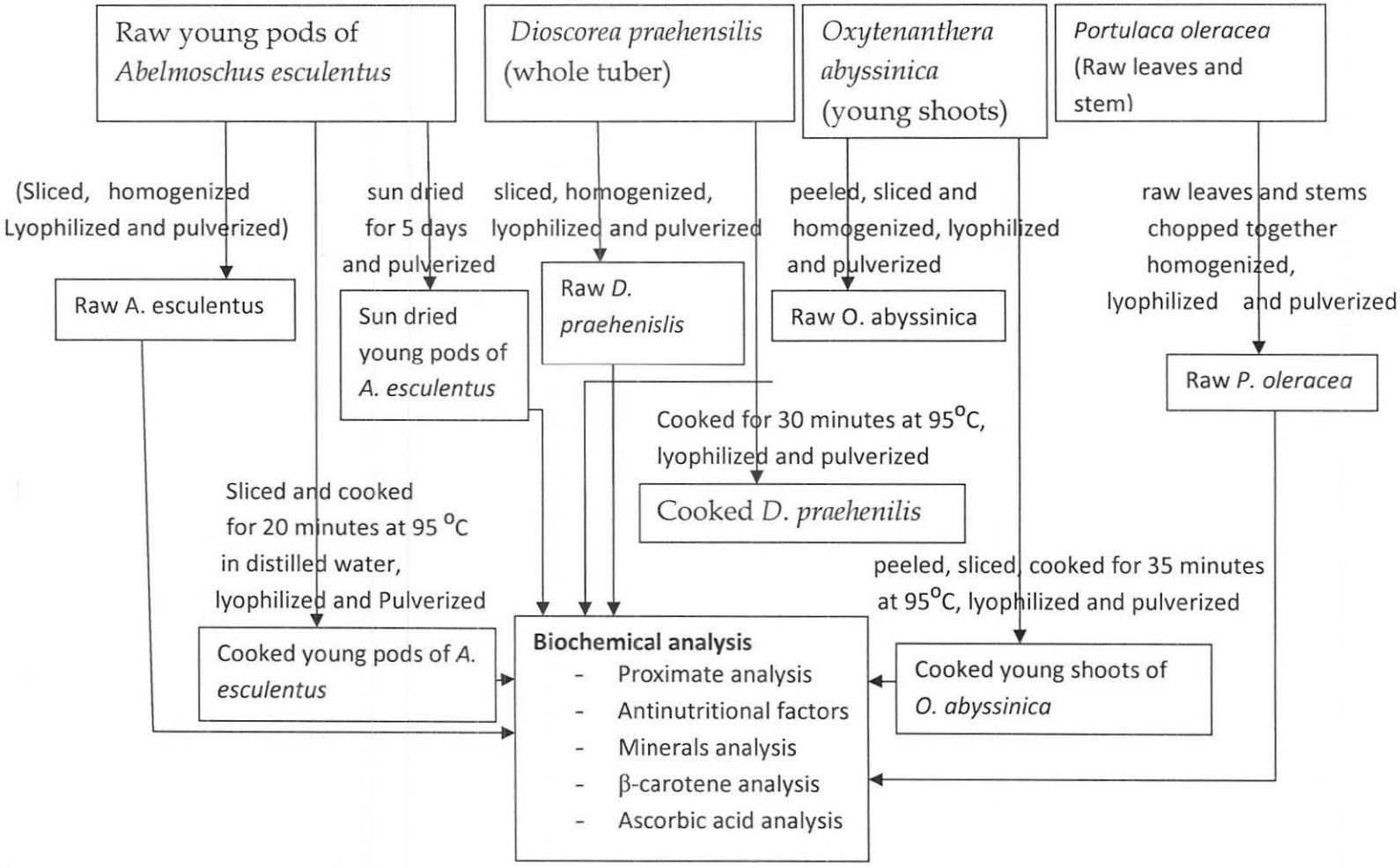
The information obtained from household interview on the ways of processing the vegetables at the household level was used to prepare the samples for chemical analysis. Processing methods of vegetables were similar across all the households interviewed even though the ingredients to be added to the vegetables may vary depending on the availability of the required recipe and economic status of the family.

Table 2: Selected wild and cultivated vegetables, their cultivation status and parts consumed and form of consumption.

Botanical Name	Local Name	Life form	Cultivation status	Parts used and form of consumption
Abelmoschus esculentus (L.) Moench.	Okra(E) Qenqetse (B) Andeha (G)	Annual herb	Cultivated	Immature pods and leaves cooked and consumed as a soup
Dioscorea praehensilis Benth.	Wild Yam(E) Echa(G,O)	Perennial herb	Wild	The tuber is boiled, peeled and eaten
Portulaca oleracea L.	Posulane(E) Bella(G) Kawa (Sh)	Annual succulent herb	Exist as cultivated and wild	Raw aerial part is chopped with other spices and eaten as a soup
Oxytenanthera abyssinica (A. Rich.) Munro	Bamboo (E) Enta(G) Somo(O)	Tree (woody culms)	Wild	Young bamboo shoots are peeled cooked and consumed

E=English name, B=berta, G=gumuz, Sh=shinasha, O=Oromifa

3.3. General flow chart for sample preparation



3.4. Chemical analysis of selected vegetables

Proximate compositions (moisture, crude fiber, crude protein, crude fat, and ash), minerals (Ca, Cu, Fe, Zn, K, Na, and P), vitamin C, β-carotene and antinutritional factors (phytate, total phenolics, tannin, oxalate, alkaloids and cyanogenic glycosides), were determined from raw and processed vegetable samples.

3.4.1. Determination of the moisture content

Empty drying dishes (made of porcelain) were dried using a drying oven (Germany, Memmert) for 1 hour at 105 °C. The dishes were cooled for 30 minute in desiccators with granular silica gel and weighed using a digital analytical balance to the nearest milligram (W_1). About 5.000 g of fresh samples were weighed (W_2) in dried and pre-weighed drying dishes. The dishes and their contents were then placed in drying oven and dried for 5 hours at 105 °C. The dishes and their contents were cooled in desiccators to room temperature and weighed (W_3). The procedure was repeated until a constant weight was attained (AOAC, 2005).

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

3.4.2. Determination of crude protein

The protein content of the samples was determined on the basis of total nitrogen content by micro Kjeldahl method of crude nitrogen determination (AOAC, 2005). Two grams of dried sample was digested in a 100-mL Kjeldahl digestion flask by boiling with 6mL of concentrated H_2SO_4 acid and 3grams of Kjeldahl digestion tablet (selenium: potassium sulphate mixture) as a catalyst and boiling point raising agent. 3.5ml of 30% hydrogen peroxide was added to the digestion mixture after which the teccator tube containing the mixture was set with teccator digestor. The digestion was continued for 4 hours at 370 °C until the mixture became a clear solution.

The digested sample solution was made up to 50 ml with distilled water and 30 ml of 40% sodium hydroxide. The solution was slowly and automatically added to the mixture by Kjeldhal titration apparatus. The ammonia liberated was collected in 30 ml of 1% boric acid solution containing a mixed indicator. Steam was applied to the solution to distill out ammonia evolved with the distillate collected into the boric acid solution. Ammonia was estimated by titrating with standard 0.1N HCl solution. Blank nitrogen determination was carried out in a similar manner and subtracted from the sample nitrogen. Crude protein was determined by multiplying the value obtained for percentage nitrogen content by a factor of 6.25.

Calculation:

$$\%N_2 = \frac{14 \times M \times V_t \times V_{100}}{\text{Weight of sample (mg)} \times V_a}$$

$$\%\text{Crude Protein} = \%\ N_2\ (\text{Nitrogen}) \times 6.25$$

Where, M = Actual molarity of Acid

V = Titer value (Volume) of HCl used

V_t= Total volume of diluted digest

V_a = Aliquot volume distilled

3.4.3. Determination of crude fat

Ether extractives as an estimate of crude lipid was determined using Soxhlet extraction apparatus by exhaustively extracting a known weight of sample by diethyl ether. Two gram of dried sample was weighed in extractor thimble (W1). A clean, dried round bottom extraction flask containing a few granules of boiling chips were weighed (W2). The extraction thimble and flask was fitted on the extractor unit and 60 ml of diethyl ether was poured into the flask using a tube connected on the top of the extraction unit. Condenser was connected to the Soxhlet extractor and cold water circulation was put on. The heating mantle was switched on and the heating rate adjusted until the solvent was refluxing at a

steady rate. Extraction was carried out for 4 h. The solvent was recovered and the oil dried in an oven set at 70 °C for 1 h. The round bottom flask and oil was cooled in a desiccator and then Weighed (W3) (AOAC, 2005). The ether extract was calculated as:

$$\% \text{ Crude fat} = \frac{W3 - W2}{W1} \times 100$$

3.4.4. Determination of crude fiber

Acid-base digestion method was used to determine the crude fiber content. Two gram sample was weighed in 600mL beaker, 200mL 1.25% H_2SO_4 was added and the mixture boiled for 30 minutes on hot plate in the fume hood. After exactly 30 minutes, 20 ml 28% KOH was added and the mixture again boiled gently for further 30 minutes, while stirred occasionally. The hot solution was quickly filtered under suction. The residue was washed several times with hot distilled water and then by 1% H_2SO_4 and filtered. After rinsing the residue with distilled water, it was washed with 1%NaOH. The crucible containing the residue was once again washed with distilled water and finally by 1% acetone. The washed residue was dried in an oven at 100 °C to constant weight and cooled in a desiccators and weighed (C1). The weighed residue was ashed in a muffle furnace at 550 °C for 2 h, cooled in a desiccator and reweighed (C2). Crude fiber content was expressed as percentage loss in weight on ignition (AOAC, 2005).

Calculation: The loss in weight on incineration = C1-C2

$$\% \text{ Crude fiber} = \frac{C1 - C2}{\text{Weight of original sample}} \times 100$$

3.4.5. Determination of Carbohydrate

Carbohydrate was estimated by difference as described by FAO (1998) as follows:

% Total carbohydrate = 100 - (% moisture + %Ash + % fat + % Protein + % Fiber)

3.4.6. Determination of total ash and minerals

Ash was determined using AOAC (2005). The porcelain crucible was dried in an oven at 100 °C for 10 min, cooled in desiccators and Weighed (W1). Two grams of the finely ground sample was placed into a previously weighed porcelain crucible and reweighed (W2); it was first charred on the hot plate in the fume hood until it was completely decarbonized and then transferred into a furnace which was set at 550°C. The sample was left in the furnace for six hours to ensure proper ashing. The crucible containing the ash was then removed; cooled in desiccators and Weighed (W3). The percentage ash content was calculated as follows:

$$\% \text{ Ash Content} = \frac{W3 - W1}{W2 - W1} \times 100$$

The methods of AOAC (2005) were used to determine minerals. Accordingly, all the crucibles required for minerals analyses were washed with 6N HCl and glass wares with 10% nitric acid. The required number of crucibles was placed in an oven for 30 minutes at 100°C, cooled in desiccators for 30 minutes and weighed (W1). One gram of samples were accurately weighed and subjected to chare at hot plate starting from low temperature under a hood. The samples were ashed in a muffle furnace at 475°C for 1 hour and the crucibles were taken out from the furnace, cooled, and moistened with a few drops of deionized water. The water was evaporated on a hot plate. The samples were ashed once more for 30 minute at 475°C and cooled in the crucible; some drops of deionized water and 5 drops of concentrated HNO_3 were added and evaporated on hot plate as described above. Finally, the samples were ashed as above for 30 minutes at the same

temperature as previously described. The crucibles were cooled in desiccators for 45 minutes and then weighed (W2). Six ml of 6N HCl was added to the ashed sample to wet it completely and carefully taken to dryness on a low temperature hot plate. Seven ml of 3N HCl was added and the crucible heated on the hot plate until the solution just boils. Then the solution was cooled and filtered through a Whatman No 1 filter paper into a 50 ml graduated flask. Five ml of 3N HCl was added to the crucibles and the solution was heated until it starts boiling, cooled and filtered into the graduated flask. The crucibles were washed at least three times with deionized water and the washings were filtered into the flask. Five ml of lanthanum chloride solution per 100 ml of solution was added to the extract to free bounded calcium. The content of the flask was cooled and diluted to the volume of the flask with deionized water. The sample extract solution was transferred to polyethylene bottle and stored until used for determinations of minerals. Blank was prepared without sample by taking the same amount of reagents under the same condition.

The minerals, *viz.* calcium, iron, zinc, and Cu were analyzed using Shimadzu atomic absorption spectrophotometer (AA-6800/ "AA Wizard" software). Sodium and potassium contents were determined using flame photometer (Jenway, PF 7, Essex UK) according to the method described by AOAC 2005,966.16 and 965.30, respectively. Briefly, two grams of dried samples were weighed in 250 ml conical flask and 20 ml of diluted nitric acid (1:1 ratio with deionized water) was added. The mixture was digested by gently boiling on a hot plate for 10 minutes. The digest was cooled and filtered into 100ml volumetric flask. The conical flask and residue left on the filter paper was washed several times with deionized water and the volumetric flask containing the filtrate was made to the mark with deionized water. Fifty ml of the extract was taken from the filtrate and added into another 100ml volumetric flask for sodium analysis. Five ml of previously prepared diluted potassium chloride

solution was added and the volume was filled to the mark with deionized water. For potassium determination, 5 ml of the same extract was added into 100ml volumetric flask and the volume was made up to the mark with deionized water. Blank solution was prepared in a similar manner without addition of the sample extract. Sodium and potassium was determined from the aliquots of solutions using flame photometer.

Phosphorous was determined using UV-visible spectrophotometer (CECIL Instruments, Cambridge England, deuterium F 500mA, power T3. 15A) based on AOAC (2005) method 970.39. Briefly, 1ml of the digested solution for mineral analysis was taken into 100ml volumetric flask and the volume was filled to the mark with deionzed water. From the aliquots, 5 ml of the solution was taken into test tubes in a duplicate to which 0.5 ml molybdate was added and homogenized. Aminonaphtholesulphonic acid (0.2 ml) was added to the mixture and mixed. Series of standards were prepared in a similar manner and the mixture was left to stand for ten minutes. Absorbance of standard, blank and samples were read at 660 nm using UV Visible Spectrophotometer. Absorbance versus concentration calibration curve was constructed and the equation obtained was used to calculate the unknown phosphorus concentration in the samples.

$$\text{Phosphorus in mg/100gm} = \frac{(A_S - A_B)*\text{dilution factor}*\text{extracted volume}*100}{\text{Slope}*\text{weight of sample}*1000}$$

Where, A_s= absorbance of sample

A_B= absorbance of blank

Slope= from the calibration curve

3.4.7. Energy value

Energy was calculated using the Atwater system as described by the World Health Organization (1982) by multiplying the values obtained for each of the

protein and carbohydrates by 4 and fat by 9.00. The results were expressed in kilocalories per hundred grams of dry weight.

$$\text{Energy (kcal/100g)} = (\%\text{fat}*9 + \%\text{protein}*4 + \%\text{carbohydrate}*4)$$

3.4.8. Determination of provitamin-A carotenoid (β-carotene)

Extraction of β-carotene

β-carotene was determined based on Rodriguez-Amaya and Kimura (2004). Accordingly, 5g of fresh and processed vegetable samples was extracted by homogenizing with 100 ml cold acetone in a mechanical blender and 0.1% BHT, in acetone, was added as an antioxidant. The extract was filtered into a flask by whatman number 1 filter paper and the residue was washed three times until the samples became colorless. The residue was discarded and the filtrate was combined with 20gm anhydrous sodium sulfate as a desiccant. The anhydrous sodium sulfate was removed through filtration and the volume of the extract was reduced by rotary evaporator under reduced pressure and temperature less than 35 °C. The extract in the rotary evaporator was collected by 10 ml 80% acetone in water. The extracts of dark green vegetables were saponified with equal volume of 10% KOH in methanol overnight. The carotenoids were extracted with acetone and water so that the final extract contained 80% acetone.

Standard preparation

Stock solution of beta carotene was prepared by taking 10mg in 100ml HPLC grade n-hexane. The concentration of stock solution was equal to 100 ppm. The stock solution was diluted to different known concentration; 0, 5ppm, 10ppm, 20 ppm, 50 ppm and 100ppm and dilutions were obtained in 5 ml of n-hexane solution.

β-carotene analysis

Perkin Elmer HPLC programme containing LC-1000 pump (Isocratic), having C18 column and connected with LC 250 UV/VIS detector was used. HPLC was calibrated by running mobile phase (HPLC grade Acetonitrile, dichloromethane and methanol by the ratio of 70:20:10, respectively) at the flow rate of 2ml per minute. Wave length was fixed at 452 nm. The pressure of the column was kept 1800-2000 PSI. Each working standard solution and samples (20µl) were injected into HPLC system at the Laboratory of Food, Medicine and Health care Administration and Control Authority of Ethiopia (FMHACA). The standard curve was constructed with five different concentrations (0, 5, 10, 20, 50 and 100ppm) against the peak area (Annex, 1). The concentration of β-carotene in the sample was calculated as follows:

$$C_x\ (\mu g/g) = \frac{A_x \times C_s\ (\mu g/mL) \times \text{total volume of extract (mL)}}{A_s \times \text{sample weight (g)}}$$

Where C_x = concentration of β-carotene X; A_x = peak area of β-carotene X; Cs = concentration of the standard; A_s = peak area of the standard

3.4.9. Determination of ascorbic acid

According to the method of Al-Duais et al. (2009), 5g of each sample was extracted with 100mL 6% trichloroacetic acid using mortar and pestle for 5 minutes and the solid suspensions were removed by centrifugation (5000 rpm, 5 min). The sample extract was filtered into 250ml conical flask. Two drops of saturated Bromine solution was added to the flask containing the sample extract and aerated. Ten milliliters of 2 % thiourea was added to the flask containing the extract and homogenized. Four ml of the same solution was pipetted into each of three test tubes. One ml 2, 4-dinitrophenylhydrazine was added to each of the two test tubes letting one test tube aside as a blank. All the test tubes were placed in water bath at 37°C for four hours. The test tubes were taken out of the water bath and cooled in an ice bath for 5 minutes. Five ml 85% H_2SO_4 was slowly

added into each test tubes while the tubes were in an ice bath. One ml of 2% DNPH was added to the blank and all the tubes were mixed. The tubes were left to stand in the dark place at room temperature for 30 minutes. The absorbance of standard solutions, blank and the samples were measured at 515 nm using UV-Visible Spectrophotometer. L-Ascorbic acid diluted to different concentrations was used as a standard (0, 10, 20, 30, 40 and 50 ppm). Standard curve of concentrations vs. absorbance readings was prepared (Annex, 2) and regression equation was developed to determine the level of ascorbic acid in the samples. All analysis was done in duplicate.

3.5. Determination of Anti-nutritional factors

3.5.1. Phytic acid

The phytate content was determined as described by Latta and Eskin (1980), and later modified by Vaintraub and Lapteva (1988). Briefly, 0.5gm of dried sample was extracted with 10ml of 0.2N HCl for 1hour at an ambient temperature and centrifuged (3000rpm for 30m). The clear supernatant was used for the phytic acid determination. Two ml of wade reagent (0.03%$FeCl_3.6H_2O$ and 0.3%Sulfosalcilic acid) was added to 3ml of the supernatant sample solution. The solution mixture was homogenized and centrifuged (3000rpm/10minut). The absorbance was measured at 500nm using UV-Visible spectrophotometer. The amount of phytic acid was calculated using phytic acid standard curve prepared (Annex, 3) in the same condition and the result was expressed as phytic acid mg/100g dry weight.

3.5.2. Oxalate

The oxalate content of the samples was determined using titration method (Adeniyi et al., 2009; Inuwa et al., 2011). Two g of finely ground samples were placed in a 250 ml conical flask containing 190 ml of distilled water. Ten ml 6M HCl solution was added to each of the samples and the suspension digested at 100°C for 1h. The samples were then cooled and made up to 250 mL mark of the

flask. The samples were filtered and duplicate portion of 125 ml of the filtrate were measured into beaker and four drops of methyl red indicator was added, followed by the addition of concentrated NH_4OH solution (drop wise) until the solution changed from pink to yellow colour. Each portion was then heated to 90°C, cooled and filtered to remove the precipitate containing ferrous ion. Each of the filtrate was again heated to 90°C and 10 mL of 5%$CaCl_2$ solution was added to each of the samples with stirring consistently. After cooling, the samples were left overnight. The solutions were then centrifuged at 2500 rpm for 5 min. The supernatants were decanted and the precipitates completely dissolved in 10 mL 20% H_2SO_4. The total filtrates resulting from digestion of 2 g of each of the samples were made up to 200 mL. Aliquots of 125 mL of the filtrates were heated until near boiling and then titrated against 0.02 M standardized $KMnO_4$ solutions to a pink colour which persisted for 30 sec. The oxalate contents of each sample were calculated (Munro and Bassiro, 2000). The analysis was carried out in duplicate, and the results were expressed in dry basis.

3.5.3. Total polyphenols

Total phenolics was determined using Folin_Ciocalteu reagent (Singleton et al., 1999). 100 mg of grounded dry plant material was weighed into a test tube. A total of 5ml of 80% aqueous methanol was added, and the suspension was stirred slightly. Tubes were sonicated for 40 min at 40°C in a sonicator bath and centrifuged (14000 rpm for 10 minutes). Supernatants were collected and the amount of total phenolics in the extract was determined according to the Folin_Ciocalteu procedure (Singleton and Rossi 1999). One hundred µl of the extract was added into each of two test tubes for each sample; 2.5 ml Folin_Ciocalteu's reagent and 1.5ml 20 % sodium carbonate was added to the mixture. The tubes were mixed and incubated for 30 min at 40°C. Absorption was read at 765 nm using UV-Visible spectrophotometer. Series of standard solutions (0, 50, 100, 150, 250 and 500ppm) were prepared using pure gallic acid

obtained from Modern and Traditional Medicine Research Department of EPHI. All the standards and blank were treated as the sample extract described above and the absorbance read at the same wavelength. The calibration curve was constructed using Microsoft Excel sheet and linear regression equation was obtained (Annex, 4). The total phenolic content was expressed as Gallic acid equivalents in milligrams per gram of dry material.

3.5.4. Condensed tannin

Tannin was determined based on the method of Maxson and Rooney (1972). Briefly, 1 gram of sample was weighed in a screw cap test tube and 10 ml of 1%HCl in methanol was added to the test tubes containing samples. The test tubes were placed in a mechanical shaker for 24 hrs at room temperature. The tubes were then centrifuged at 1000 rpm for five minutes. One milli litter of the supernatant was taken from the test tubes and mixed with 5 ml of vanillin-HCl reagent in other test tubes. After waiting for 20 minutes, so that the reaction completed, the absorbance was read at 500nm using UV-visible spectrophotometer. Series of standard solutions was prepared using D-catechin as the standard and calibration curve was prepared at different concentrations (0, 12, 24, 36, 48 and 60 ppm). Tannin concentration was calculated from the linear regression equation obtained and expressed as D-catechin equivalent.

3.5.5. Cyanogenic glycosides

The total cyanogenic glycosideds were determined in accordance with AOAC (2005). Ten grams of ground and homogenized sample was placed in the extraction flask and 100 ml of distilled water was added. The samples were macerated for 2 hours at room temperature. Additional 100 ml distilled water was added and the flask containing the extract was connected to the distillation apparatus adjusted for cyanide analysis. The distillate was collected into 20 ml 0.01N $AgNO_3$ solution acidified with 1 ml concentrated HNO_3. The distillate was

filtered into 100ml conical flask and excess AgNO3 was back titrated against 0.02N KSCN using ferric alum indictor.

$$HCN\ (mg/100g\ sample) = [(V_{AgNO3}*1.08)]*100/W$$

1mL 0.01N $AgNO_3$ = 0.27mg HCN

3.5.6. Total alkaloids

The total alkaloids in the vegetable samples were determined gravimetrically (Adeniyi et al., 2009; Inuwa et al., 2011). Five grams of each of the samples were dispersed into 50 mL of 10% acetic acid in ethanol; the mixtures were shaken and allowed to stand for 4hs and filtered. The filtrate was evaporated to one quarter of the original volume. Concentrated NH_4OH was added to each of the samples drop wise to precipitate the alkaloid. The precipitate was filtered off with weighed filter paper (W1) and washed with 1% NH4OH solution. The precipitates in each case were dried at 60°C for 30 min and reweighed (W2).

$$\%\ Total\ alkaloids = \frac{W2-W1}{S_{wt}} x100$$

Where, W1=the weight of empty filter paper

W2=the weight of filter paper and alkaloids

S_{wt}= is the sample weight

3.6. Minerals bioavailability

There are many techniques used to predict the bioavailability of minerals in the human body from plant foods. One of the methods is by measuring the molar ratio of antinutrient/minerals in the food and diet (Morris and Ellis, 1989). The proportion of samples with ratios above the suggested critical values were determined: calcium:phytate <6 (Morris and Ellis, 1989), phytate : iron > 1 (Hallberg et al., 1989), phytate : zinc >15 (Morris and Ellis, 1989), phytate : calcium/zinc> 0.5 (Davies et al., 1985; Bindra et al., 1986). The antinutrient to

minerals molar ratios were used by many researchers to predict bioavailability of minerals (Adeyeye et al., 2000; Gargari et al., 2007; Gibson et al., 2007; Norhaizan and Nor Faizadatul Ain, 2009 and Umeta et al., 2005).

3. 7. Statistical analysis

Descriptive statistics such as means and standards deviation were calculated using SPSS version 16 software. One way analysis of variance (ANOVA) was used to see the effect of household processing methods on the nutrient, anti-nutrient and mineral bioavailability of selected vegetables. Multiple comparison tests using least significant difference technique (LSD, $p<0.05$) were applied to compare the means of each parameter between different household processing practices using SPSS version 16 software. Paired comparison t-test was used to determine if there was a significant mean difference between raw and processed vegetables for each parameter.

4. Results and discussion

4.1. The effect of processing on proximate compositions of young pods of *Abelmoschus esulentus*

The proximate compositions such as moisture, protein, crude fat, crude fiber, total ash, total carbohydrate and the gross energy values of raw and processed (as practiced by the community at household) young pods of *Abelmoschus esculentus* are presented in Table 3. The moisture contents of immature pod of *Abelmoschus esculentus* was slightly increased after cooking. Marginal increment in moisture content during cooking was as a result of rapture of the cell wall by heat and hence increased water absorption capacity. The result in the level of moisture content of young pods of *A. esculentus* is in agreement with previous report (Nwachukwu et al., 2014). The higher moisture contents of this vegetable may create conducive environment for multiplication of micro organisms (Muhammad et al., 2011) and may shorten its shelf life.

The crude fat content of immature pod of *A. esculentus* was 1.1% dry basis and cooking of this vegetable does not have much effect on the level of the crude fat as it is basically poor. The protein content of young pods of *A. esculentus* did not significantly varied between the raw and cooked samples but shows statistically significant reduction in the sun dried samples. The negative effect of sun drying on the protein content might be associated with the resistant of nitrogen to digestion as a result of sun drying. The crude fiber and total ash content of raw *A. esculentus* immature fruit were 12% and 8%, respectively. These results are in line with the values of Adetuyi and Osagie (2011). The authors reported fiber content of *A. esculentus* within the range of 10.5 - 11.63%, and ash level of 7.19 - 9.63%, respectively. The results showed that the fiber and total ash contents of *A. esculentus* were significantly reduced ($p<0.05$) by cooking but not sun drying. The reduction of ash might be due to the leaching of minerals to cooking water. Young fruits of *Abelmoschus esculentus* contained appreciable

amount of carbohydrate and energy and hence could be a good source of energy to the community consuming this vegetable.

Table 3: Proximate compositions (g/100 g) and caloric values (Kcal/100g) of raw and processed study vegetables

Species, plant part		Moisture % Fb	Protein	Ether extract	Crude fiber	Total ash	Total CHO	Energy Kcal/100g
A. esculentus, immature pod	RAS	89.1±.4^{a}	16.8±.5^{b}	1.13±.1^{a}	11.6±.4^{b}	8.7±.29^{b}	58.4±.17^{b}	309.1±2.6^{b}
	CAS	91.1±.8^{b}	16.3±.24^{b}	1.2±.01^{a}	10.7±.15^{a}	7.7±.28^{a}	59.58±.5^{b}	314.4±2.6^{b}
	SAS	88.9±.1^{a}	15.24±.4^{a}	1.2±.05^{a}	11.4±.14^{b}	9.4±.99^{b}	52.03±1.3$^{a\,b}$	281.3±4^{a}
D. praehensilis, tuber	RDP	68.7±.4^{a}	8.34±.07^{b}	0.25±.06^{b}	3.01±.09^{b}	4.1±.59^{b}	76.9±.74^{a}	343.3±3.2^{a}
	CDP	72.2±.4^{b}	7.32±.08^{a}	0.06±.01^{a}	2.60±.12^{a}	1.4±.12^{a}	85.26±.42^{b}	370.9±1.7^{b}
P. oleracea, aerial part	RPO	88.1±.2	17.37±.5	2.76±.11	14.10±.2	21.5±.44	41.83±.54	261.3±1.1
O. abyssinica, young shoot	ROA	91.1±.6^{a}	30.2±.56^{b}	6.9±.44^{a}	8.16±.07^{a}	11.4±.9^{a}	35.43±.17^{a}	316.7±5.3^{a}
	COA	94.1±.27^{b}	27.0±.54^{a}	7.6±.17^{a}	8.3±.57^{a}	11.5±.2^{a}	34.77±.42^{a}	313.3±1.7^{a}

Fb= Moisture is on fresh basis and all others are on dry basis; Plants parts: RAS=raw, CAS=cooked, SAS= sundried; RDP=raw, CDP=cooked, RPO=raw, ROA=raw, COA=cooked; Values are expressed as mean ± SD of two determinations; Mean values in the same column for each species followed by different superscript letters were considered significant at $p<0.05$

The energy values of raw, cooked and sundried young pods of *A. esculentus* were 309.1 Kcal/100g, 314.4Kcal/100g, and 281.3 Kcal/100g DM, respectively. These values are similar with the findings of Sorapong (2012).

4.2. The effect of processing on proximate compositions of *Dioscorea praehensilis* (wild yam)

The proximate compositions of raw (whole) and cooked (peeled) tubers of *D. praehensilis* are presented in Table 3. The slight increase in moisture content of cooked tuber of *D. praehensilis* indicate its water holding capacity because of hydrophilic constituents such as carbohydrates and crude fiber. Marginal increment in moisture content during cooking were similarly observed in different varieties of wild yam (Sahore and Amini, 2013). As expected, negligible amount of crude fat was determined in both raw and cooked tuber. The crude fat content of *D. praehensilis* obtained in the present study is lower than reports of Shajeela (2011) on different species of wild yams but the protein value for *D. praehensilis* well agreed with their findings. Although the protein content in the tuber was found to be significantly reduced through boiling, the change in magnitude was not noteworthy in view of the level of the protein in the raw sample. Reduction in protein during heat treatments might be attributed to denaturation and leaching to the cooking water, which is not traditionally consumed/not estimated (Choudhury et al. 2010). Roots and tuber crops including *D. praehensilis* are generally low in protein. Hence, food products from these crops should be supplemented with other high protein products for balanced nutrition (Lewu et al., 2009). There were significant ($p<0.05$) reductions in crude fiber and total ash contents of cooked *D. praehensilis* when compared to the whole tuber. These reductions might be attributed to the peeling off of the tuber bark after boiling. The fiber and ash content of the bark may be responsible for the variation. The carbohydrate and energy values of the tuber are significantly enhanced after boiling (Table, 3). Higher metabolisable energy values obtained in the cooked *D. praehensilis* was in line with the findings of Olajide et al. (2011). The total carbohydrate and energy values reported for taro (*Colocasia esculenta*) grown in Ethiopia were 85.65% and 372.55Kcal/100g respectively (Adane et al., 2013) and are almost congruent with *Dioscorea*

praehensilis. Although there is no report on nutritional composition of *D. praehensilis* to our knowledge, its tuber is a good energy source similar to other tuber crops widely consumed in Ethiopia such as taro and cassava (Adane et al., 2013).

4.3. The effect of processing on proximate compositions of young shoots of *Oxytenanthera abyssinica*

Fresh young shoots of lowland bamboo (Oxytenanthera abyssinica) had moisture content of 91.1% and slightly increased to 94.1% upon cooking (Table 3). The low crude fat and high fiber content of young shoots of O. abyssinica could make them to be recommended as weight reducing diet since low fat and high fiber foods reduce the level of cholesterol and obesity (Whitney and Rolfes, 2008). The protein content of young shoots of *O. abyssinica* was comparable with the values previously reported for different bamboo species (Chongtham et al., 2011). The statistically significant ($p<0.05$) reduction during cooking (or other heat treatments) might be due to either degradation or chemical changes like oxidation or by leaching into the cooking medium (Olajide et al. 2011) Generally, this vegetable can be considered as good protein source on dry basis. However, it must be noted that bamboo shoot is consumed on fresh basis and their macronutrient composition gets diluted by the higher moisture content of the vegetable. Furthermore, the quality and bioavailability of the protein is of higher benefit than the gross protein quantity of the vegetable. The respective crude fiber and total ash contents between the raw and cooked lowland bamboo shoot (*Oxytenanthera abyssinica)* did not significantly vary. The crude fiber content (8.16-8.3%DM or 0.55-0.78%FW) obtained for *Oxytenanthera abyssinica* in the current study was less than the value reported for the other varieties of bamboo shoots which were within the range of 2.26-4.5%FW but its total ash content was within the range of previous report (0.68-1.38%) (Chongtham et al., 2011). As can be seen, the metabolisable energy value determined from raw and cooked *O.*

abyssinica were 316.7 Kcal% and 313.3 Kcal% DM respectively. The results show that young shoots of *O. abyssinica* are good sources of protein, carbohydrate and dietary fiber but low in fat.

4.4. The proximate compositions of *Portulaca oleracea*

Portulaca oleracea has exceptionally highest level of total ash (21.5 g/100g (DM) and crude fiber 14.1%. Higher level (23%) of total ash was also reported by Aberoumand (2008). The total ash content, which is an index of mineral contents, of *P. oleracea* gives insight that the vegetable is reach source of minerals. Food plants that provide more than 12% of their calorific value of protein are a good source of protein (Food and Nutrition Board, 2001). In that context, P. oleracea leaves and stem (17.37%) are a good source of protein.

The estimated carbohydrate content (41.83; Table 3) of *P. oleracea* was in agreement with the carbohydrate value (40.67) reported earlier (Aberoumand, 2008). Whereas the crude fiber content (14.10%) obtained in the present study was higher than the results of Aberoumand (2008). The fiber recommended dietary allowance values for children, adults, pregnant and breast-feeding mothers are 19-25%, 21-38%, 28% and 29%, respectively. Thus, the *P. oleracea* leaves and stem could be a valuable source of dietary fiber human nutrition.

The calorific value of *P. oleracea* leaves and stem was estimated to be 261.3 Kcal/100g, DW, which is an indication that it could be an important source of dietary calorie. Table 3 clearly shows that all the WEPs studied are appreciable amount of energy. Given their high crude fiber, minerals and vitamins, it is suggested that the edible wild and semi wild vegetable species analyzed in the present study may be used in enhancing the starchy staple foods of the Gumuz community such as maize and sorghum gruels.

4.2. The effect of household processing on the minerals content

Standard calibration curves

The linearity of the series of known concentration vs the absorbance is very important in determining the elemental concentration of food samples to ensure the accuracy of Atomic Absorption Spectrophotometer. The calibration curves for all elements analyzed were fairly linear as shown in Annex 5 for iron and zinc.

From the results presented in Table 4; it is noticeable that the concentration of different macro elements (Ca, P, Na, and K) and trace elements (Fe, Zn and Cu) of the wild and cultivated vegetables were high and the vegetables studied could be regarded as appreciably important source of these essential elements. Potassium is abundant in all vegetables analyzed followed by calcium, phosphorous and sodium from the macro elements. From the trace elements, iron level was relatively higher followed by zinc and copper.

The effect of processing on minerals content of young pods of *Abelmoschus esculentus*

As presented in table 4, the iron and zinc contents of raw *A. esculentus* (okra) were 2.3mg/100g and 0.68 mg/100g, respectively. The iron content of raw okra immature pods obtained in the present study was higher than findings of Adetuyi and Osagie (2011) for different okra varieties; which was within the range of 0.87-0.97 mg/100g FW but the zinc content (0.68±0.04 mg/100g FW) obtained in this study was slightly lower compared to 1.29-1.37 mg/100g FW reported by the authors. The variation in the contents of the minerals in *A. esculentus* may be due to the varietal difference or genetic factor, environmental factor and their interactions (Adetuyi & Osagie, 2011). Significant loss of iron and

zinc were observed in the cooked okra but no statistically significant between raw and sun dried young fruits of okra. This could be due to leaching of the minerals in to the cooking water. Sun drying is the gradual loss of water through evaporation and cannot support leaching. It has to also be noted that minerals are not volatile.

Table 4: Mineral content (mg/100g, fresh basis) of raw and processed vegetables

Species		Fe	Zn	Ca	Cu	P	Na	K
A. esculentus	RAS	2.33±0.37^{b}	0.68±0.04^{b}	131.7±8.3^{b}	0.11±0.01^{b}	39.14±0.95^{b}	7.82±0.28^{b}	184.4±1.3^{b}
	CAS	0.68±0.08^{a}	0.55±0.03^{a}	104.23±4.9^{a}	0.08±0.01^{a}	36.28±.067^{a}	4.4±0.29^{a}	155.4±1.7^{a}
	SAS	2.58±0.16^{b}	0.54±0.02^{a}	140.4±8.13^{b}	0.08±0.01^{a}	51.85±0.34^{c}	7.51±0.92^{b}	183.3±53.4^{b}
D. praehensilis	RDP	27.0±6.24^{b}	0.46±0.02^{b}	43.19±2.0^{a}	0.46±0.04^{b}	40.68±2.7^{b}	8.94±0.54^{b}	341.16±3.6^{b}
	CDP	1.79±0.06^{a}	0.29±0.06^{a}	40.74±6.8^{a}	0.19±0.02^{a}	23.69±2.4^{a}	5.88±0.75^{a}	128.49±3.9^{a}
P. oleracea	RPO	8.06±0.11	0.84±0.06	117.99±10.8	0.14±0.01	39.13±0.34	20.42±1.31	816. 3±11.7
O. abyssinica	ROA	0.64±0.02^{a}	0.85±0.02^{b}	24.49±1.2^{a}	0.11±0.01^{b}	57.27±0.94^{b}	7.34±0.42^{b}	456.2±12.3^{b}
	COA	0.6±0.06^{a}	0.54±0.02^{a}	22.94±4.21^{a}	0.07±0.01^{a}	39.7±1.89^{a}	4.20±0.55^{a}	273.2±1.6^{a}

RAS=raw, CAS=cooked, SAS=sundried; RDP=raw, CDP=cooked, RPO=raw, ROA=raw, COA=cooked; Values are expressed as mean ± SD of three determinations; Mean values in the same column corresponding to each species followed by different superscript letters were considered significant at $p<0.05$

The effect of cooking on minerals content of *Dioscorea praehensilis*

The iron level in raw (whole) *Dioscorea praehensilis* was 27 mg/100g FW. However, cooking and peeling the bark of the tuber significantly reduced the iron content to 1.79 mg/100g FW. The iron content of *D. preahensilis* obtained in this study in the raw sample was higher when compared with the value reported for *Dioscorea pentaphylla* (8 mg/100g FM) (Shanthakumari et al., 2008). Zinc concentration of *D. praehensilis* was also significantly reduced during cooking and debarking from 0.5 mg/100g to 0.3 mg/100g FW. The statistically significant ($P<0.05$) reduction of iron and zinc concentration upon cooking and peeling of the tuber may be because of the presence of minerals in the outer non edible part of the tuber which was removed by peeling after boiling the tuber. The same reason may apply to the minerals which showed enormous reduction in the boiled and peeled *D. praehensilis*. Reduction in zinc content was also reported in peeled and boiled tubers of *Diocorea cayenesis* (Akin-Idowu et al., 2009). The potassium level in raw tubers of *D. praehensilis* was 341.16 mg/100g. Analyses of variances show significant losses when the tubers were cooked compared to the raw samples. This loss may be attributed to the leaching out of minerals including potassium into the cooking water (Kakati et al., 2010). The high potassium content in this tuber could help to maintain normal blood pressure and can be labeled as heart protective vegetable.

The effect of cooking on minerals content of young shoots of *Oxytenanthera abyssinica*

The minerals content of raw and cooked juvenile shoots of *Oxytenanthera abyssinica* is presented in Table 4. The iron and zinc contents of juvenile shoots of *O. abyssinica* were 0.6 mg/100g and 0.9 mg/100g, respectively. The zinc content was higher in raw bamboo shoots compared to other study vegetables. All minerals tested were decreased in the cooked samples with the reduction being statistically significant in Zn, Cu, P, Na, and K but Fe and Ca were not

significantly lost in the cooked samples. The variation in the degree of loss might be related to the chemical forms of minerals in the food matrix. The respective potassium content determined in raw and cooked samples of *O. abyssinica* were 456.2mg/100g and 273.2 mg/100g fresh weight basis. The potassium content of raw *O. abyssinca* obtained in the current study is well agreed with the value reported for other bamboo species such as *Bambusa tulda* (408mg/100g, FW) and *Dendrocalamus hamiltonii* (416mg/100g, FW) (Chongtham et al. 2011). In South Asian countries, bamboos have been utilized for traditional medicine treatments to relieve hypertension, sweating, and paralysis (ERG, 2004). Anti-hypertension effect of the bamboos might be due to the substitution of sodium by potassium, which results in lowering the blood pressure. Raw shoots of *O. abyssinica* had the highest phosphorous content compared to other study vegetables. However, cooking has significantly reduced the phosphorous level. Phosphorus is a major component of bones and teeth (Otten et al., 2006).

Studies confirmed that there is no known benefit of high sodium consumption. Sodium intakes more than 1g per day tend to aggravate a genetically determined susceptibility to hypertension, and intakes above 7 g/day may induce hypertension even in individuals who have no specific genetic susceptibility (Io, 2012). In this context, all the vegetables contained safe sodium levels.

Minerals composition of *Portulca oleracea*

Portulaca oleracea has the highest iron content (8.1 mg/100g FW) (Table 4) in the edible part when compared to other vegetables included in this study. *Portulaca oleracea* is consumed as a raw sauce and as a result there is no processing effect on the minerals and vitamins available in this vegetable. The potassium content was very high in *Portulaca olercea* (816.25 mg% FW). The amount of potassium in the aerial part of *P. oleracea* was higher than spinach *(Pinacea oleracea)* (558 mg/100g) and kale (*Brasicca oleracea*) (491 mg/100g) (Table 5), which are recognized to have high potassium content.

Table 5: Minerals level in some commonly used vegetables (Umeta et al., 2005, Chongtham et al., 2011)

Common vegetables	Fe mg/100g	Zn mg/100g	Ca mg/100g	K mg/100g	P mg/100
Kale, boiled	4.6	0.71	221.4	491	57.0
spinach , raw	2.7	0.5	99.0	558	49.0
Sweet potato, boiled	0.70	0.3	23.8	337	53.0
Yam, boiled	0.8	0.58	18.6	816	55.0

The potential of the vegetables in meeting the RDA requirements of some minerals

The recommended dietary allowance (RDA) for iron is 10mg/day for adults (Whitney and Rolfes, 2008). The raw immature pods of okra could provide 116.5% of the RDA requirement for iron if 500g fresh vegetable is consumed per day, considering it would be fully bioavailable. The cooked and sundried *A. esculentus* could provide 34% and 129% RDA requirement for iron from 500g FW meal. Cooked *D. praehensilis* and bamboo shoots can also provide 89.5% and 30% RDA requirement of iron from fresh 500g meal, respectively, and only 125g fresh leaves and steams of *portulaca oleracea* can provide 100% RDA requirement for iron. Similarly, this RDA calculation did not consider the inhibitory effect of different anti-nutritional factors that affects the bioavailability of iron.

The RDA for zinc is 12 mg/day for lactating woman (Whitney and Rolfes, 2008). Five hundred grams meal (fresh basis) from cooked *A. esculentus* could provide 23% of the zinc RDA requirement for lactating mothers. Similarly, cooked *D. praehensilis* and juvenile shoots of *O. abyssinica* in the cooked form could provide

12.1 and 22.5 % RDA requirement for zinc respectively. *Portulaca oleracea* could provide 35% of RDA for zinc considering the requirement for lactating woman.

The calcium content ranged from 22.9 mg/100g FW in cooked bamboo shoot to 140.4 mg/100g FW in sundried *A. esculentus*. Raw immature fruits of *A. esculentus* contained 131.7 mg/100g fresh weight basis. The calcium level obtained in this study for *A. esculentus* grown in Ethiopia was higher than the values reported for different okra varieties in Nigeria (Adetuyi and Osagie, 2011). Raw aerial part of *P. oleracea* contained higher (118 mg/100g FW) calcium content next to sun dried and raw *A. esculentus*. The calcium content in raw and cooked *O. abyssinca* was 24.5 mg/100g and 22.9 mg/100g FW, respectively. The calcium content reported in India for the different bamboo species was within the range of (21.17-180.69 mg/100g) (Choudhury et al., 2010); and the present value obtained for *O. abyssinica* was similar with *Bambusa balcooa* (24.01 mg/100g). The calcium content shows no significant ($P>0.05$) variation between raw and boiled *D. praehensilis* and *O. abyssincia* (Table 4). However, significant reduction was observed when *A. esculentus* was cooked but sun drying did not affect the calcium content.

The RDA for calcium is 1000 mg/day for adults (Whitney and Rolfes, 2008). Consumption of 500g cooked *A. esculentus*, cooked *D. praehensilis*, and *O. abyssinica* and raw *P. oleracea* can contribute 52.12, 20.37, 11.5 and 59.0% RDA requirement for calcium, respectively. *A. eculentus* and *P. oleracea* are good source of calcium.

Copper was the element found in a trace amount in all WEPs analyzed which ranged from 0.07-0.46 mg/100g FW. This is important due to the fact that copper is required by body at a trace level for many metabolic activities (Chongtham et al., 2011).

Phosphorous content in this study ranged from 23.7 mg/100g-57.3 mg/100g FW. Raw *A. esculentus, D. prahensilis* and *O. abyssinica* contained 39.1, 40.7 and 57.3 mg/100g phosphorous, respectively. Cooking resulted in significant losses (7.3-41.76%) of phosphorus with variable degree of proportion among the vegetables (Table 4). Similar findings were reported in the earlier studies (Akin-Idowu et al., 2009). RDA for phosphorous is 700 mg/day for adults (Whitney and Rolfes, 2008). Consumption of 500g cooked *A. esculentus, D. praehensilis* and *O. abyssinica* and raw *P. oleracea* can contribute to 25.9, 16.9, 27.9 and 28.4% RDA requirement for phosphorous, respectively.

4.3. Bioavailability of minerals

Antinutritional components such as oxalates, tannins, polyphenols and phytic acid (myoinositol hexaphosphate), present in plant foods are known to have adverse effects on human nutrition by inhibiting iron (Hurrell et al., 1999) and zinc (Gibson et al., 2007) absorption.

To predict the bioavailability calcium, iron and zinc; molar ratios and their respective critical value are presented in Table 5.

Table 6: Anti-nutrient/mineral molar ratios of raw and processed vegetables

Species		[Phy]/[Zn][1]	[Ca]/[Phy][2]	[Phy]/[Fe][3]	[PhyxCa]/[Zn][4]	[Ox]/[Ca][5]
A. esculentus	RAS	6.077±0.45[a]	51.11±0.77[a]	1.50±0.001[a]	1.73±0.12[a]	0.17±0.001[b]
	CAS	5.50±0.23[a]	57.20±0.35[b]	4.07±0.35[b]	1.57±0.06[a]	0.15±0.001[a]
	SAS	7.48±0.03[b]	53.04±0.77[a]	1.68±0.06[a]	2.11±0.1[b]	0.15±0.001[a]
D. praehensilis	RDP	3.79±0.19[a]	35.0±0.50[a]	0.06±0.001[a]	0.10±0.01[a]	1.04±0.001[b]
	CDP	3.66±0.60[a]	45.63±0.84[a]	0.51±0.01[b]	0.09±0.01[a]	0.28±0.001[a]
P. oleracea	RPO	14.22±0.39	15.06±0.12	1.28±0.02	3.21±0.07	0.72±0.002
O. abyssinica	ROA	2.03±0.10[a]	22.64±0.51[a]	2.22±0.11[a]	0.12±0.01[a]	0.75±0.002[b]
	COA	3.74±0.10[b]	24.55±0.09[a]	1.81±0.13[a]	0.22±0.0[b]	0.50±0.01[a]
Critical values		15.0	6.0	1.0	0.5	2.5

RAS=raw, CAS=cooked, SAS= sundried; RDP=raw, CDP=cooked, RPO=raw, ROA=raw, COA=cooked. Values in the same column followed by the same superscript corresponding to the same species are not significantly different (P>0.05).

[1] (mg phytate/MW of phytate: mg Zn/MW of Zn), [2](mg Ca/MW of Ca: mg phytate/ MW of phytate)

[3](mg phytate/MW of phytate: mg Fe/MW of Fe), [4] (mol/Kg of phytate x mol/Kg of Ca: mol/Kg of Zn)

[5] (mg oxalate/MW of oxalate: mg Ca/MW of Ca)

The importance of foodstuffs as dietary source of minerals such as iron, zinc and calcium depends on both the total mineral contents and the level of other constituents that affect mineral bioavailability (Adeyeye et al., 2000).

Molar ratio of phytate to zinc

The calculated phytate/zinc molar ratios for raw and processed WEPs were within the range of 2.03-14.22, which were in the range of the suggested critical level (<15 regarded as favorable for zinc absorption) (Morris and Ellis, 1989). Ratios ≥15 are associated with low zinc bioavailability (Morris and Ellis, 1989). According to WHO cut-offs phytic acid to zinc mole ratio ≥15, 5-15 and <5 is equal to zinc bioavailability as low (10-15%), moderate (30-35%) and high (50-55%), respectively (Goicoechea et al., 1996). In this context, *A. esculentus* and *P.*

oleracea had moderate zinc bioavailability. Whereas, the molar ratios suggested that high zinc bioavailability could be achieved from *D. praehensilis* and juvenile shoots of *O. abyssinica*. However, The critical phytate:zinc molar ratio may also depend on dietary calcium levels because of the kinetic sinergism between calcium and zinc ions resulting in Ca:Zn:Phy complex which is less soluble than phytate complexes formed by either ions alone (Lopez et al., 2002), suggesting that Ca:phy/Zn molar ratio is better predictor of zinc bioavailability than Phy:Zn molar ratio alone.

Molar ratio of Calcium x phytate/zinc

CalciumxPhytate/Zinc molar ratios of cooked and sundried *A. esculents* and *P. oleracea* were above the critical level (0.5mol/Kg) as indicated in Table 5, suggesting that calcium interference was more likely to affect zinc bioavailability. The CaxPhy/Zn molar ratio reported in the earlier study for different okra varieties in Nigeria was within the range of 0.293-0.436 (Adetuyi and Osagie, 2011). Higher calcium content in Okra that grows in Ethiopia than in Nigeria could be attributed to genetic differences, environmental variability and interaction of the genetic factor with the environment. Considering both Phy/Zn and CaxPhy/Zn molar ratios, zinc could adequately be absorbed in the body from *D. praehensilis* and shoots of *O. abyssinica*.

Molar ratio of phytate to iron

As indicated in the table 5, phytate/iron molar ratios were >1 (indicative of poor iron bioavailability) for all raw and processed WEPs except *D. praehensilis*. This might be due to the reported higher phytate content and insufficient phytic acid degradation (4.5-27.5%) by boiling alone. Phytate reduction (13-33%) after boiling *Dioscorea sp.* was reported by (Akin-Idowu et al., 2009). *Dioscorea praehensilis* could be a better source of bioavailable iron.

Molar ratio of calcium to phytate

The Calcium/phytate molar ratios in all the raw and processed WEPs were >6, which is regarded as favorable for calcium absorption (Akin-Idowu et al., 2008), predicting that a good calcium bioavailability could be achieved from all the selected vegetables. In addition to phytic acid, oxalic acid in insoluble form is responsible for interference of divalent metals absorption particularly calcium by forming insoluble salts (Hassan and Umar, 2004).

The oxalate/calcium molar ratios of all the selected raw and processed vegetables were below the critical level of 2.5 known to significantly impair calcium bioavailability suggesting that they are good calcium bio-resources for the local populace.

4.4. The effect of processing on β-carotene

The β-carotene content of the studied vegetables is shown in Figure 8. The highest β-carotene was obtained in raw leaves and stems (chopped together) of *P. oleracea*. On the other hand, β-carotene was not detected in the tubers of *D. praehensilis* both in raw and cooked samples.

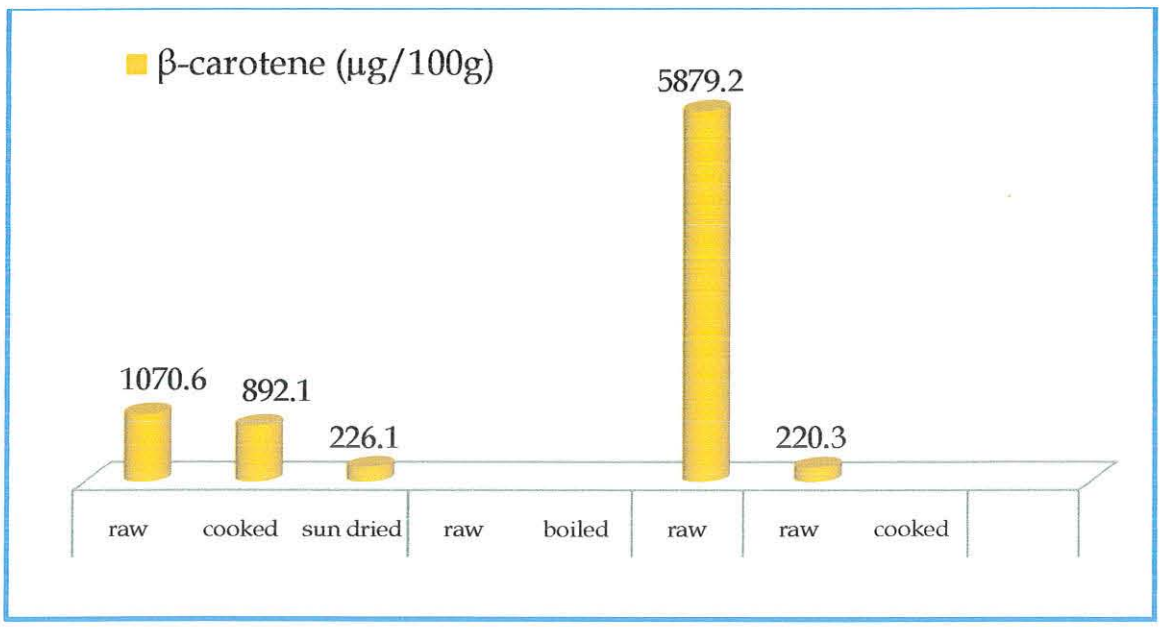


Figure 7: Beta carotene levels in the raw and processed vegetables

The level of β-carotene (vitamin A precursor) in *P. oleracea* was 5879.2 µg/100g DM, which is equivalent to 489.9 retinol activity equivalent (RAE), 1 RAE = 12 µg (Otten et al., 2006). The β-carotene which is known to be the main provitamin A carotenoid was in the range of Trace-5879.2 µg/100g DM in the raw samples and Trace to 892 µg/100g DM in the cooked samples. The β-carotene level in *P. oleracea* obtained in this study (5879.2 µg/100g DM) was in line with the previous report for the wild porsulane (4350 µg/100g DM) (Uddin et al., 2014). The β-carotene content of young immature okra pods for the raw, cooked and sundried samples in µg/100g DM were, 1070.6, 892.1 and 226.1, respectively, and ascorbic acid content was 25.8, 21.1 and 10.8 mg/100g DM, respectively. The β-carotene level in raw *A. esculentus* in this study was slightly lower than the value reported

by Sorapong (2012). Cooking and sun drying *A. esculentus* significantly reduced the β-carotene level with the highest loss observed in sun dried young pods of *A. esculentus* (Figure, 8).

The retention of β-carotene after cooking the immature pods of *A. esculentus* was 83.3% on dry weight basis. Enormous destruction of β-carotene was observed after sun drying as the retention was only 21.1%. Cooking young shoots of *O. abyssinica* destroyed the β-carotene completely as can be seen on the chromatogram (Annex, 5). The complete loss could be due to combination of the low β-carotene content in the raw bamboo shoots and prolonged cooking. This loss of β-carotene is due to the fact that carotenoids are heat labile compounds and undergo oxidation and degradation upon exposure to heat (Mortensen and Skibsted, 1997). *Portulaca oleracea* was the highest both in β-carotene and ascorbic acid content compared to the other WEPs investigated in the present study. The way the local communities consume this vegetable (raw together with other ingredients) benefits them as it avoids destruction of the micronutrients such as minerals, β-carotene and vitamin C. However, the high antinutritional factors recorded in *p. oleracea* require careful processing method to reduce their levels and increase bioavailability of inorganic nutrients. However, the processing method should not significantly damage vitamins and other phytochemicals (such as antioxidants) of biomedical importance.

The RDA for vitamin A is 700-900 μg retinol activity equivalents (RAE/day) for adults, whereas children and infants require 500 μg RAE/day (Whitney and Rolfes, 2008). Consumption of 500g FW meal from *P. oleracea* leaves and steams could provide 27.2 % RDA requirement for Vitamin A considering the highest RDA (900 μg RAE/day). Since retention of carotenoids in cooked *A. esculentus* was low and almost none in *D. praehensilis* and *O. abyssinica*, they are not a good source of Vitamin A to fulfill the RDA requirement. Only 4% RDA requirement

for vitamin A could be obtained by consumption of 500g fresh weight of cooked *A. esculentus*.

4.5. The effect of processing on ascorbic acid

The ascorbic acid content of *P. olercea* obtained in the present study (60.41mg/100g DM) was much lower than the one reported for wild porsulane (451mg/100g DM) (Uddin et al., 2014). Significant difference ($P<0.05$) in the ascorbic acid content was observed in cooked and sundried young pods of *A. esculentus* compared to the raw samples. Similarly, the ascorbic acid content in the raw *D. praehensilis* (9.5 mg/100gDM) has dropped to 2.9 mg% DM after cooking. Processing methods utilizing heat can irreversibly inactivate ascorbate oxidase, thus counteracting enzymatic decomposition. However, reduction of L-ascorbic acid may also occur as a function of thermal decomposition and leach into the cooking medium (Davey et al., 2000).

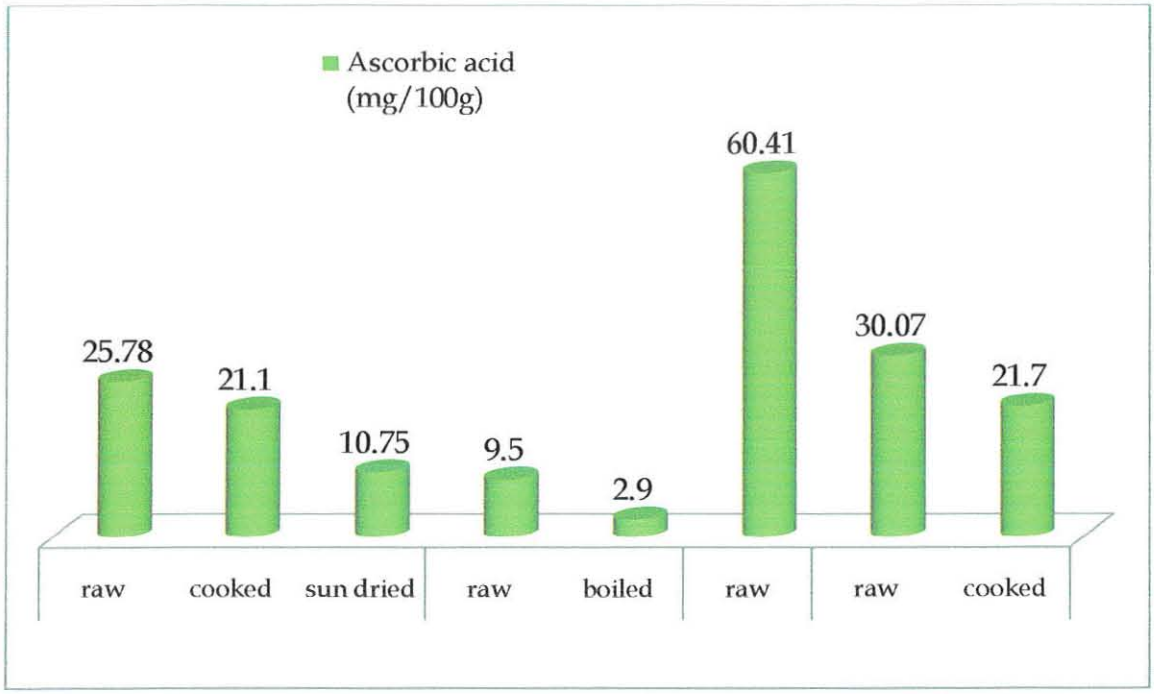


Figure 8: Ascorbic acid contents in the raw and processed study vegetables

In fresh bamboo shoots, the ascorbic acid retention in the cooked sample was 72.1%. Similarly, significant loss of ascorbic acid upon cooking tubers of *D. praehensilis* and *O. abyssinica* (young shoots) was observed.

Ascorbic acid retention after cooking *A. esculentus* for 20 munutes and sun drying for five days was 81.8% and 41.7%, respectively. The ascorbic acid retention in cooked *D. praehensilis* and *O. abyssinica* was 30.5 and 72.16%, respectively. Previous study on different wild yam cultivars by Akin-Idowu et al. (2009) reported ascorbic acid retention of 36.4-48.4% and the decrease in ascorbic acid content in the boiled tuber in the present study was similar phenomena to the one reported by the authors. The amount of ascorbic acid in young shoots of *O. abyssinica* obtained in the present study was 30.1mg/100g DM and 21.7 mg/100g DM for the raw and cooked samples respectively. This result was in agreement with the value reported in a research review by Chongtham et al. (2011). Significant loss of ascorbic acid was observed in cooked and sundried *A. esculentus*, the highest loss being in sundried sample. Previous study confirmed that boiling significantly decreases the level of vitamin C in vegetables and prolonging boiling duration aggravate the loss (Agbemafle et al., 2012). It is therefore suggested that boiling of vegetables should be done within the shortest possible time to retain most of these nutrients.

The recommended dietary allowance for ascorbic acid is between 40-90 mg/day for infants and adults (Whitney and Rolfes, 2008). Significant contribution to ascorbic acid RDA requirement could be achieved if 500g FW *P. oleracea* is consumed, thus providing 36.5-82.3% of the RDA.

4.6. Influence of household processing methods on antinutrient contents of selected WEPs

The anti-nutritional components like total oxalate, phytate, tannin, total polyphenols, alkaloid and cyanogenic glycocides (HCN) were studied in fresh and cooked selected edible wild and semi wild vegetables and the mean values in all the species are presented in table 6. A decreasing trend was found in all antinutritional factors in the cooked vegetables. Tannin was the predominant antinutritive factor in *Abelmoschus esculentus*. Whereas, *P. oleracea* exhibited higher oxalate content followed by phytate.

Table 7: Anti-nutritional composition (mg/100g, dry basis) of raw and processed vegetables

Species		oxalate	Phytate	Tannins *	Total polyphenol **	HCN mg/100gFW	Total alkaloids
A. esculentus	RAS	449.3±4.7^{b}	368.7±4.7^{b}	3233.6±2.7^{c}	55.7±0.34^{b}	BDL	3.5±0.1^{b}
	CAS	392.47±2.3^{a}	337.9±9.3^{a}	2952.5±9.02^{a}	53.4±0.3^{a}	BDL	3.16±0.4^{b}
	SAS	386.8±0.45^{a}	369.7±1.8^{b}	3137.8±5.9^{b}	54.84±0.31^{b}	BDL	0.53±.01^{a}
D. praehensilis	RDP	261.24±2.31^{b}	52.4±0.7^{a}	9.1±1.3^{a}	22.67±0.06^{b}	13.52±.18^{b}	1.22±.01^{a}
	CDP	67.1±0.47^{a}	38±1.1^{a}	4.98±0.74^{a}	14.8±0.18^{a}	7.02±.28^{a}	1.03±.01^{a}
P. oleracea	RPO	1470.4±1.4	989.8±4.75	363.7±19.5	36.4±0.2	BDL	5.13±.02
O. abyssinica	ROA	398.3±2.36^{b}	170.6±3.42^{a}	11.26±1.17^{a}	74.87±1.69^{b}	22.99±.13^{b}	10.48±.3^{b}
	COA	268.3±2.35^{a}	159.2±1.02^{a}	10.4±0.55^{a}	63.70±1.67^{a}	14.19±.03^{a}	8.15±.19^{a}

BDL= below detection limit, RAS=raw, CAS=cooked, SAS=sundried; RDP=raw, CDP=cooked, RPO=raw, ROA=raw, COA=cooked; values are expressed as mean ± standard deviation of duplicate determinations. Values in the same column corresponding to each species followed by different superscript are significantly different at $p<0.05$, *=expressed as D-catechin equivalent, **=expressed as gallic acid equivalent per gram

All the antinutritional factors were significantly ($P<0.05$) affected by cooking of the selected vegetables. The oxalate level was exceptionally high in *portulaca oleracea* (1470.4 mg/100g DM). The oxalate content of purslane leaves was 671-869 mg/100 g fresh weight (Uddin et al. 2014). The oxalate content of raw and processed *A. esculentus* in this study was within the range of 324-506 mg/100g, which is reported in different okra varieties in Nigeria (Adetuyi and Osagie, 2011). Oxalate is one of the antinutritional factors, which are widely distributed in plant foods and known to interfere with calcium absorption by forming insoluble salts of calcium (Gupta et al., 2005). The oxalate content of raw *D. praehenislis* was 261.2 mg/100g DM. Cooking and debarking of *D. praehensilis* reduced the total oxalate by 74.3%. This loss is high compared to the oxalate reduction observed in cooked and sundried *A. esculentus,* which was 12.6% and 13.9%, respectively. The amount of total oxalate determined from raw *D. praeheinsilis* in the present study is similar to the oxalate content in *Dioscorea wallichi* (260 mg/100g) but much lower than the oxalate content of *Dioscorea bulbifera* (780mg/100g) and *Dioscorea alata* (580mg/100g) (Olajide et al. 2011). The total oxalate content in juvenile shoots of *O. abyssinica* decreased from 398.3 mg/100g to 268.3 mg/100g DM. Savage (2000) indicated that boiling reduce the oxalate content of vegetables due to leaching of the oxalate into cooking water. The inconsistent degree of oxalate reduction in different species in this study is similar to a variable percentage losses obtained by Savege (2000). The oxalate level was reduced by 37 % in Broccoli (*Brassica oleracea*), by 23.3% in Rhubarb stalks (*Rheum rhaponticum*), 53% in Spinach (*Spinacia oleracea*) and by 25.1% in NZ spinach (*Tetragonia expansia*) in the cooked samples when compared to the raw vegetables (Savage, 2000).

In addition to hampering bioavailability of minerals, ingestion of vegetables containing higher level of oxalate has been linked with calcium oxalate kidney stone formation (Holmes and Kennedy, 2000). Consumption of oxalates may

therefore result in kidney disease and a high ratio of Ox:Ca in the diet may also cause chronic calcium deficiency (Judprasong et al., 2006; Sotelo et al., 2010).

The phytate content of *P. oleracea* obtained in the present study (989.8 mg/100g) is comparable with the earlier report on the same vegetable (823 mg/100g) (Aberoumand, 2012). The phytate content in the dry matter of raw of *A. esculentus* was 368 g/100g. This value is within the range (264-384 g/100g) of Adetuyi and Osagie (2011) findings for different okra varieties in Nigeria. The knowledge of the phytate level in foods is necessary because high concentration can cause adverse effects on bioavailability of nutrients (Aberoumand, 2012). Phytate forms stable complexes with Cu2+, Zn2+, Co2+, Mn2+, Fe2+ and Ca2+ (Frontela et al.,2008; Hurrell et al., 2004). In the present study, the level of phytate was significantly reduced in cooked *A. esculentus* ($P<0.05$) as compared with the fresh. *Dioscorea praehensilis* tubers have fairly low phytate contents (Table 6). The raw and cooked young shoots of *O. abyssinica* had the phytate content of (170.6 g/100g DM or 16.82 mg/100g FW) and (159.2 g/100g DM or 10.46 mg/100g FW) respectively. Report of Sarangthem and Singh (2013) show that the phytate content of young shoots of *Dendrocalamus hamiltonii* and *Bambusa balcooa* as 36mg/100g FW and 30.7mg/100g, FW respectively, which is slightly higher than the phytate content of the low land bamboo shoot (*O. abyssinica*). Even though phytate reduction was observed during cooking of bamboo shoot, the difference was not statistically significant ($P>0.05$). Literature sources indicate that phytate is known to be heat resistant (Shimi and Hashah, 2013). The lowest and highest percent phytate reduction was observed in sundried *A. esculentus* (4.5%) and boiled *D. praehensilis* (27.5%), respectively. Phytate is water soluble and when it is cooked in water, which is discarded, the amount of phytate could be reduced (Shimi and Hashah, 2013). This explained the significant reduction of phytate in boiled and peeled *D. praehensilis* since the water used for boiling was discarded. According to Kakati et al. (2010), boiling alone do not promote phytate reduction

unless the media (boiling water) to which antinutrient leaches is discarded. Hence, the Ethiopian low land bamboo shoot (*O. abyssinica*) has fairly low level of phytate. Lower level of phytate in vegetables has a positive impact on bioavailability of minerals. The presence of phytate in foods has been associated with reduced mineral absorption due to its structure which has high affinity towards minerals and form stable complexes that prevent intestinal absorption (Lopez et al., 2002).

The tannin level obtained in immature pods of raw, cooked and sundried *A. esculentus* was 3359.26 mg/100g, 3089.5 mg/100g and 3272.48 mg/100g DM respectively. The result shows statistically significant ($P<0.05$) difference in tannin level between raw, cooked and sundried samples (Table 6). The tannin content of young fruits of *A. esculentus* in this study is consistent with those reported in Elfadil et al. (2013) but higher than the value reported by Tsumbu et al. (2012) as tannin content of okra to be 600 mg/100g. The reason for interspecific and intraspecific variation in nutritional and antinutritional compositions could be attributed to variability in genetic and environmental factors such as climatic and soil conditions, altitude as well as extraction methods during analysis (Gargari et al., 2007). The tannin content of raw young shoots of *O. abyssinica* was 11.3 mg/100g DM. The level of tannin in *O. abyssinica* was similar with young shoots of *Fargesia yunnanensis* 1.71 mg/100g FW) (Wang et al., 2009). Tannins have been reported to form complexes with minerals and proteins and thus reduce their digestibility and palatability (Polycarp et al., 2012). However, their contents in foods are known to be reduced through cooking due to the fact that hydrolysable and most condensed tannins are water soluble (Ashok and Upadhyaya, 2012) and consequently leach into boiling water. The reduction upon cooking could be attributed to the degradation of the compound by the heat treatment as tannins are heat labile (Kakati et al., 2010).

Hydrogen cyanide was not detected in *A. esculentus* and *P. oleracea* but detected in *D. praehensilis* and *O. abyssinica*. The hydrogen cyanide content of raw *D. praehensilis* was 13.5 mg/100g. Boiling and debarking of *D. praehensilis* tuber reduced the cyanide concentration by 48.1 %. The cyanide level in *D. praehensilis* is higher than the values reported earlier for *Dioscorea* species (0.11-1.12 mg/100g, DM) (Shanthakumari et al., 2008). Cooking bamboo shoot also significantly ($P<0.05$) reduced the cyanide content from (~23mg/100g) to (~14.2mg/100g) fresh weight basis. According to Choudhury et al. (2012), complete elimination/detoxification of hydrogen cyanide can be achieved by two hours cooking. The study showed that the total cyanogenic glycosides, responsible to release hydrogen cyanide, in *O. abyssinca* was lower compared to widely consumed bamboo species in Asian countries; *Dendrocalamus giganteus* (89.4mg/100g) but similar with *M. bambusoides* (14mg/100g) and higher compared to *Bambusa pallid* (4mg/100g) as reported by Choudhury et al. (2012). The quantity of cyanides in bamboo shoots varies depending upon genetic and environmental factors, location of cultivation, season and soil type, parts of the shoot and time of harvest (Choudhury et al., 2012). The decrease in HCN concentration may be due to the volatile nature of the compound.

The mean total polyphenolic content as gallic acid equivalent (GAE) of the vegetables investigated was within the range of 14.8 mg/g GAE in boiled *D. praehensilis* to 74.87mg/g GAE in raw *O. abyssinica* on dry matter basis. Total polyphenols in young pods of raw, cooked and sundried *A. esculentus* were 55.7 mg/g GAE, 51 mg/g GAE and 51.7 mg/g GAE, respectively. Significant ($P<0.05$) reduction up on cooking the okra pods was observed. Reduction but not statistically significant variations between raw and sundried samples were observed. The total polyphenols level in raw young fruits of *A. esculentus* obtained in the present study is in agreement with those reported by Ahiakpa et al. (2013). According to Tsumbu et al. (2008), the polyphenols of *A. esculentus* was

the responsible agent for the anti-oxidant, anti-inflammatory properties of *Abelmoschus esculentus*. The present study showed that *A. esculentus* is rich source of dietary polyphenols in spite of the inverse correlation observed between high non hydrolysable polyphenols and non-heam iron absorption (Gillooly, 1983).

All the vegetables investigated in this study have high total polyphenolic content. Shajeela et al. (2011) found the total polyphenols in different *Dioscorea* species ranging from 220 mg/100g to 790 mg/100g. The total polyphenols content of *D. praehensilis* was higher than the values reported previously (Shajeela et al., 2011) for *Dioscorea bulbifera* var *vera* (220 mg/100g), *Dioscorea spicata* (260 mg/100g), *Dioscorea tomentosa* (410 mg/100g), *Dioscorea alata* (680 mg/100g) and *Dioscorea esculenta* (790 mg/100g). Table 6 shows that boiling and debarking of the tuber of *D. praehinsilis* significantly reduced the total polyphenols with a rate of 34.6%. The reduction of total polyphenols after boiling was consistent with the significant loss of total polyphenols in *Cyperus esculentus*, which was about 48% (Adekanmi et al., 2009). The total polyphenolic content of *P. oleracea* in our study was 36.4 mg/g GAE DM or 433.1 mg GAE/100g FW. Our result agreed with the finding of Uddin et al. (2014) who reported the TPC of *P. oleracea* to be (478 mg/100g) GAE fresh weight basis. Poeydomenge and Savage (2007) concluded that *Portulaca oleracea* is a rich source of important nutrients such as minerals and antioxidants. The presence of polyphenols, alkaloid, saponin, tannin, flavonoid, anti-oxidant and anti inflammatory activities of the aerial part of *P. oleracea* was reported by different authors (Cai et al., 2004; Facciola, 1990; Shafi and Tabassum, 2013; Tan et al., 2013).

Phenols are one of the most commonly occurring groups of phytochemicals that are of considerable physiological and morphological importance in plants as they play an important role in growth and reproduction, protect the plants against pathogens and predators, and contribute toward color and sensory characteristics of fruits and vegetables. It has also been determined that the

antioxidant capacity of bamboo leaves is due to their high polyphenol content (Chongtham et al., 2011). Several *in vivo* studies have reported the beneficial effect of dietary polyphenols and confirmed their linkage to modulation of cellular signaling processes, reduction of inflammatory molecules (Kim et al., 2005), as well as up-regulation of endogenous antioxidant enzymes (Pinto et al., 2013). On the other hand, high consumption polyphenolic compounds are correlated with poor iron absorption (Gillooly et al., 1983).

When alkaloids occur in food in higher level, they cause gastro-intestinal upset, neurological disorders and other health problems. Harvey et al. (1985) reported that alkaloids of more than 1 to 13 mg per kg body weight are considered a toxic dose for human being. The present finding of alkaloids content in both fresh and cooked or boiled shoots was below the toxic level.

5. Conclusion and recommendations

5.1. Conclusion

The preliminary ethnobotanical study showed that the Gumuz ethnic community frequently uses edible plants of wild and semi-wild origin as supplement or main dish in their diet. The nutritional evaluation studies on young pods of *Abelmoschus esculentus*, aerial parts of *Portulaca oleracea* and juvenile shoots of *Oxytenanthera abyssinica* consumed by the Gumuz community, indicated that they are good sources of crude fiber, carbohydrate, gross energy, essential minerals and phenolic compounds. However, *Dioscorea praehensilis* (tuber crop) was only rich in carbohydrate and energy value.

Except *D. praehensilis,* the wild and semi wild edible plant parts have appreciable micronutrient compositions such as iron, zinc, potassium, copper, calcium, ascorbic acid and β-carotene. However, cooking significantly reduced some of the minerals, vitamin C and pro-vitamin A carotenoid (β-carotene). Reducing duration of cooking time and using other processing methods such as fermentation (*D. praehensilis* and *O. abyssinica)* might alleviate the deterioration of the nutrients. The predicted mineral bioavailability shows adequacy in terms of calcium and zinc (moderately bioavailable) but not in iron. Hence, there is a need for some enhancers to increase iron absorption in all species. The study results further revealed that *A. esculentus* and *P. oleracea* are rich sources of bioavailable calcium. With the exception of *D. praehensilis,* the vegetables are rich in potassium and can contribute in maintaining normal blood pressure and its heart protective role.

To be able to justify the overall nutritional value of the wild and semi wild edible vegetables, proper assessment of the type and concentration of their antinutrients is necessary. The results showed presence of anti-nutrients such as phytic acid, tannin, total oxalate, total polyphenols and alkaloids in all vegetables to various degrees. Moreover, *Dioscorea praehensilis* and young shoots of *Oxytenanthera*

abyssinica have hydrogen cyanide in the tubers. A decreasing trend of all antinutritional factors was observed in the cooked vegetables. The rate in reduction of antinutritional factors depended upon the type of processing (cooking and sun drying) and vegetable. However, the reduction of phytic acid, oxalate and tannins by traditional cooking methods alone was not adequate to the level that could improve iron and zinc bioavailability.

The vegetables have higher moisture content and are mostly used after cooking as side dishes by the community. The combination effects of these factors might reduce the actual impact of antinutritional factors in impairing bioavailability of nutrients and/or causing ill health. However, appropriate processing methods that are known to reduce the antinutritional factors (such as fermentation) can be encouraged in the community.

In addition to be the rich sources of macro and micro-nutrients, the underutilized vegetables studied were found to have high amount of total polyphenol, indicating the potential antioxidant and anti-inflammatory activities of the vegetables. In this study, only the total polyphenolic content of the edible wild and semi-wild plant species have been analyzed. Further research work on quantification of the different phenolic compounds is warranted. This investigation can serve as a basis for selecting promising species for more detailed studies to meet the nutritional requirements and nutraceutical properties.

5.2. Recommendations

The promotion of agrobiodiversity and emphasis on locally available resources such as traditional, neglected and under-utilized vegetables with the value and potential to strengthen the entire agriculture-food-nutrition structure among the rural poor is feasible way forward to improve the Ethiopia's lowest rank in terms of fruit and vegetable consumption. Therefore the following recommendations are accordingly forwarded based on the study findings.

- Young pods of *A. esculentus*, aerial part of *P. oleracea* and young shoots of *O. abyssinica* were found to be good sources of micronutrients. Therefore, their promotion for wider use by the Gumuz community and elsewhere in other parts of Ethiopia where there is conducive environment for their cultivation is recommended to contribute in a food based strategy aimed at ameliorating micronutrient deficiency.
- Tuber of *D. praehensilis* has higher level of carbohydrate and energy source. However, it contains poor quantity of protein, fiber, total minerals and fat. Therefore, it is recommended to be used in combination with food ingredients that are rich in macronutrients mentioned above and micronutrients.
- The traditional processing methods have poorly reduced the level of antinutrtional factors. Therefore, alternative processing techniques that can effectively reduce the individual antinutrients is suggested to be designed and promoted in the community and other parts of Ethiopia where these vegetables are used.
- Since the availability and use of all the vegetables included in the present study are seasonal, preservation methods that prevent spoilage, nutritional composition and sensory acceptability needs to be investigated.

- The present investigation has focused on the nutritional compositions of the wild and semi-wild vegetables and their bioavailability. Further research work is required to find out productivity and economic potential of the vegetables.
- In view of global (including Ethiopia) climate change and variability, promotion of diversified food sources including underutilized edible plants that can tolerate marginal agroclimatic conditions is of paramount importance. Inclusion of the study vegetables in the agricultural and dietary system can be a useful strategy in overcoming the challenge.

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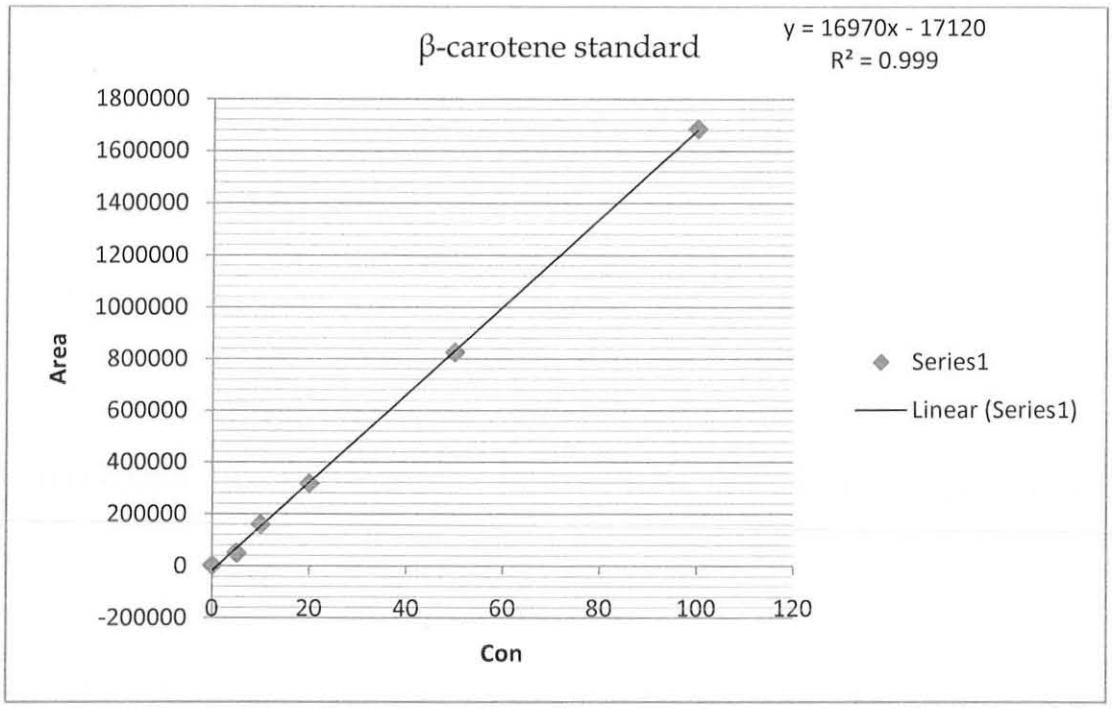
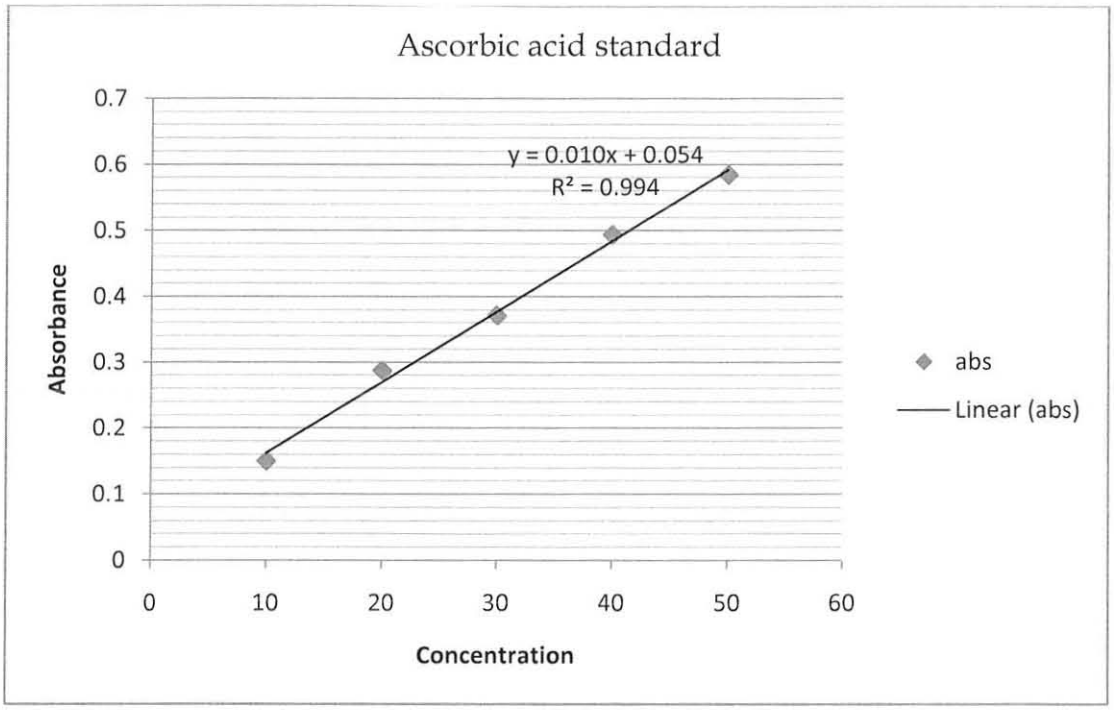
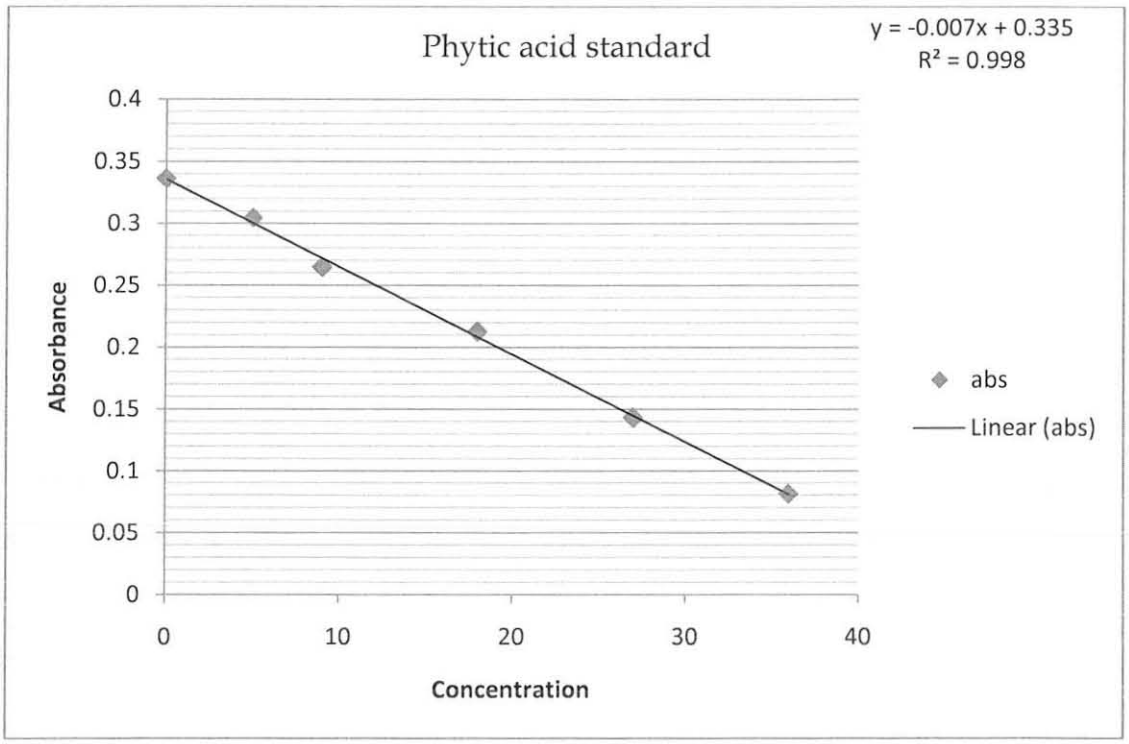
Annex 1. Beta carotene standard calibration curve



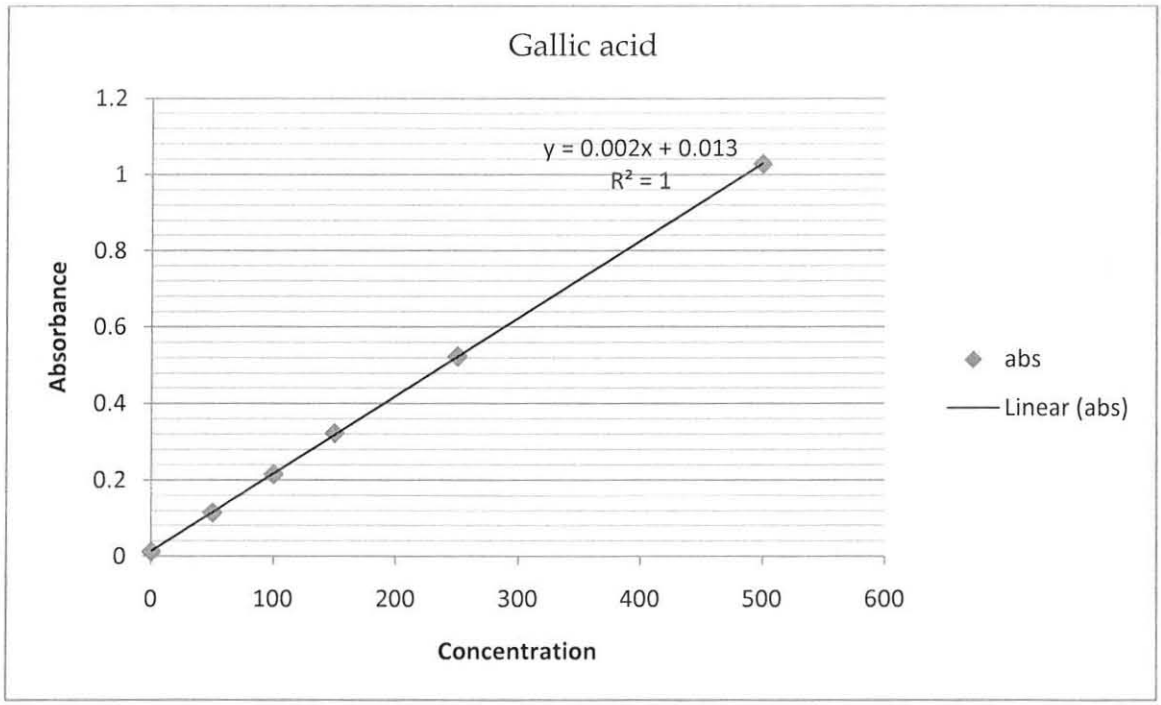
Annex 2. Ascorbic acid standard calibration curve



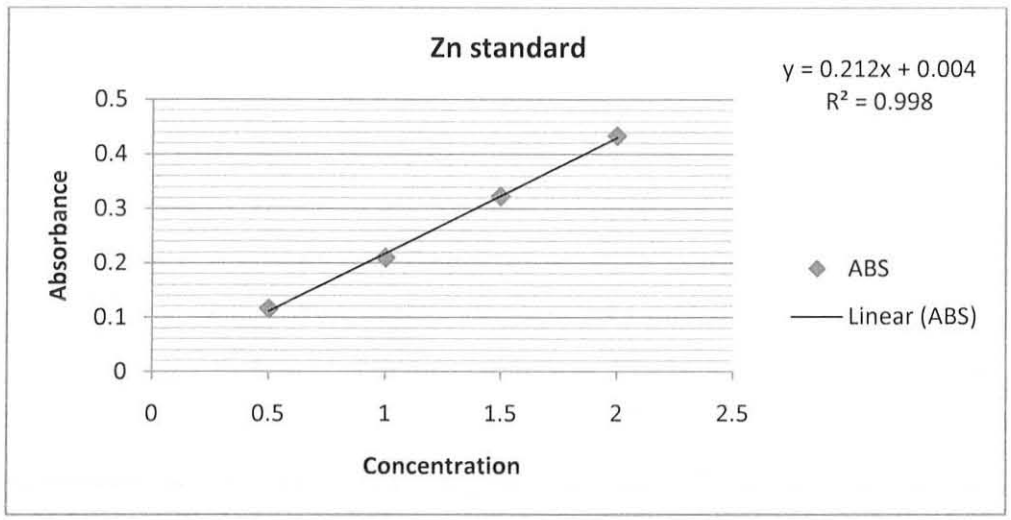
Annex 3. Phytate standard calibration curve

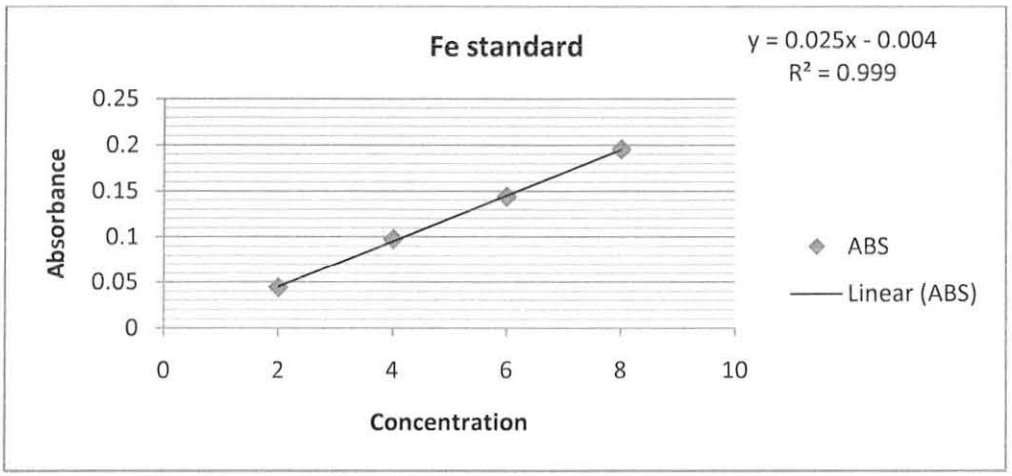


Annex 4. Gallic acid standard calibration curve

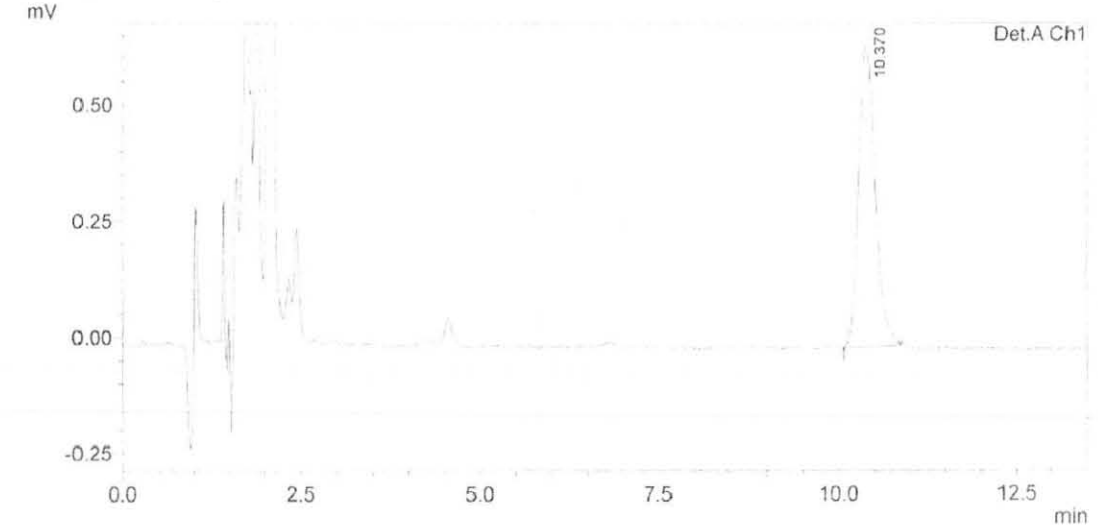


Annex 5: Zinc and iron calibration curve

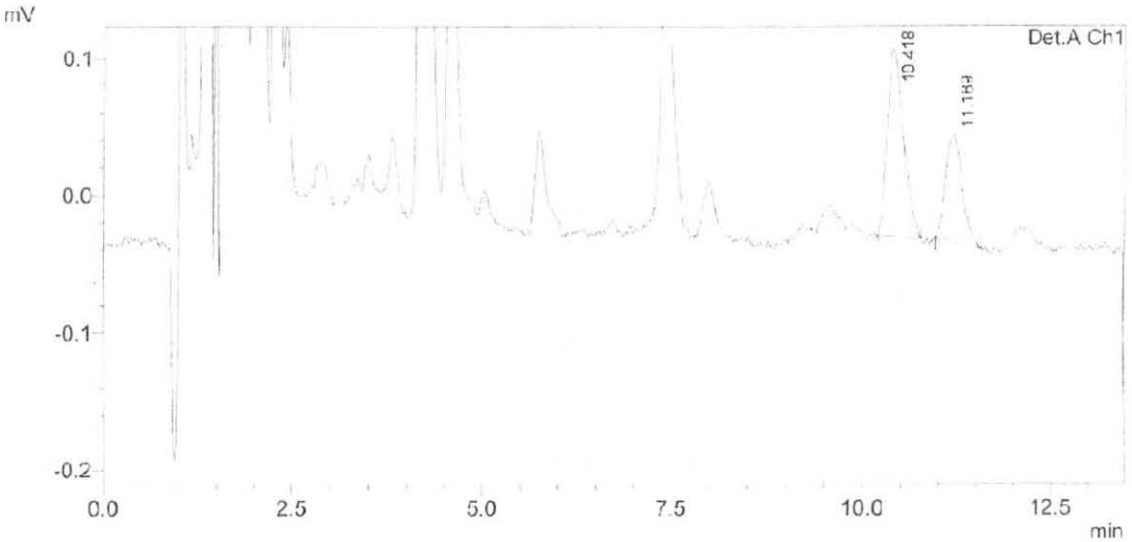




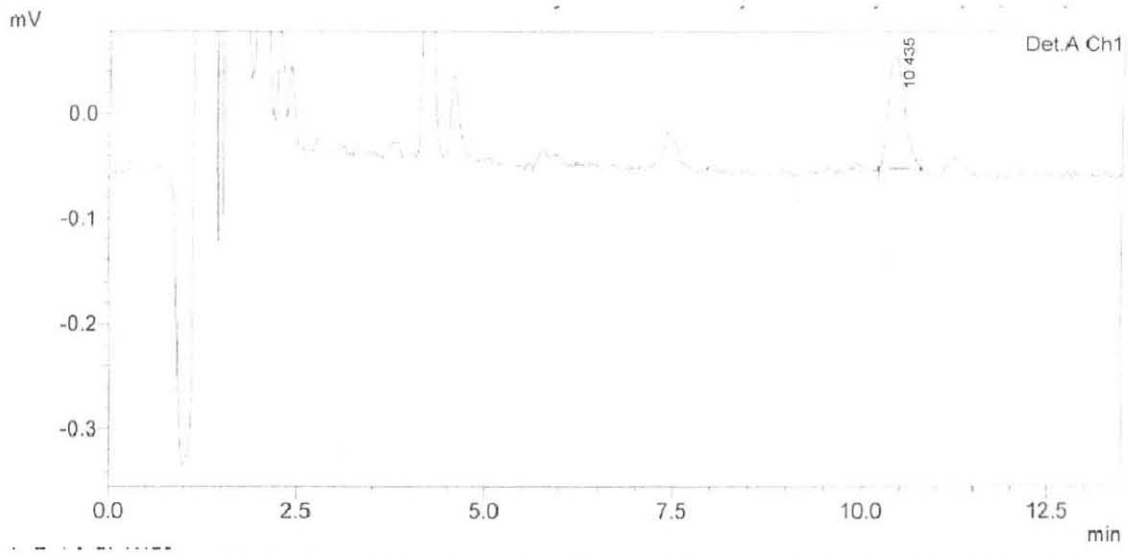
Annex 6: HPLC chromatograms and UV-Visible spectra of the β-carotene of raw, cooked and sun dried WEPs. Column-monomeric C18 Spherisorb ODS2, 5µm, 4.6 x 150 mm; mobile phase – acetonitrile: dichloromethane:methanol (70:20:10); low rate – 2mL/min.



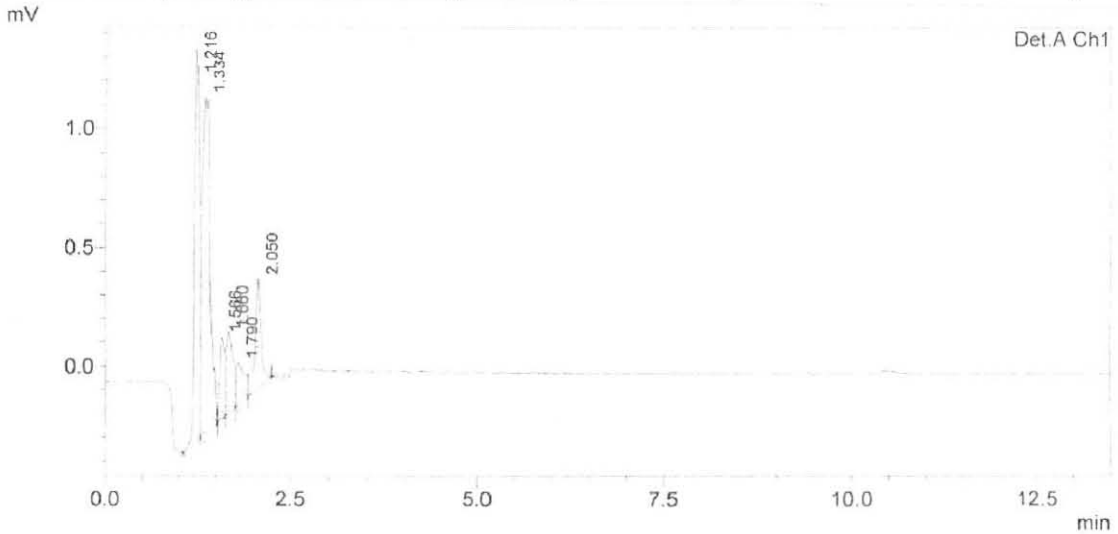
Raw immature pod of *A. esculentus* (β-carotene peak observed at 10 min)



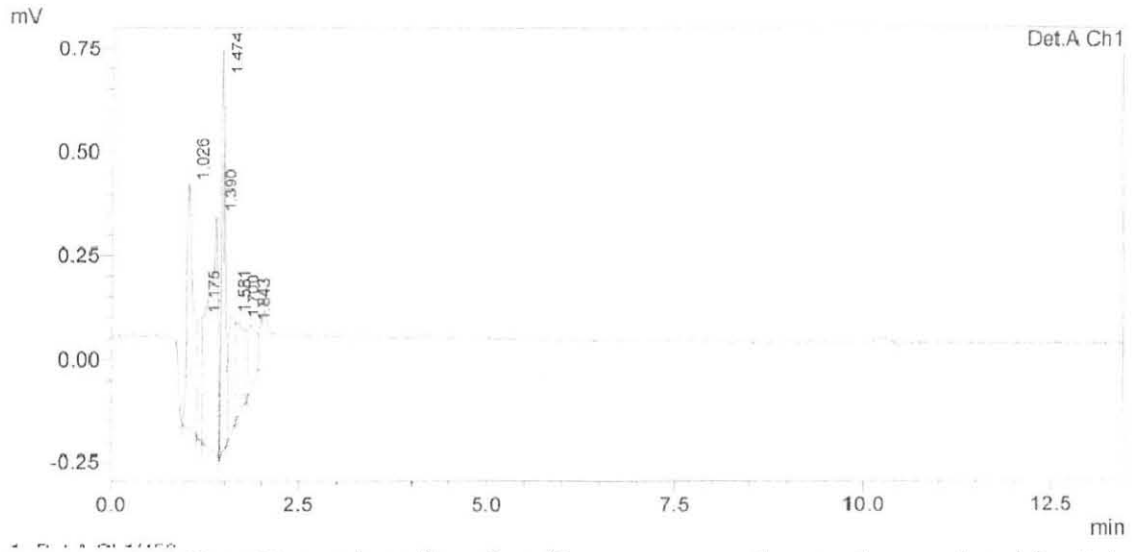
Sundried immature pod of *A. esculentus* (β-carotene peak observed at 10 minutes)



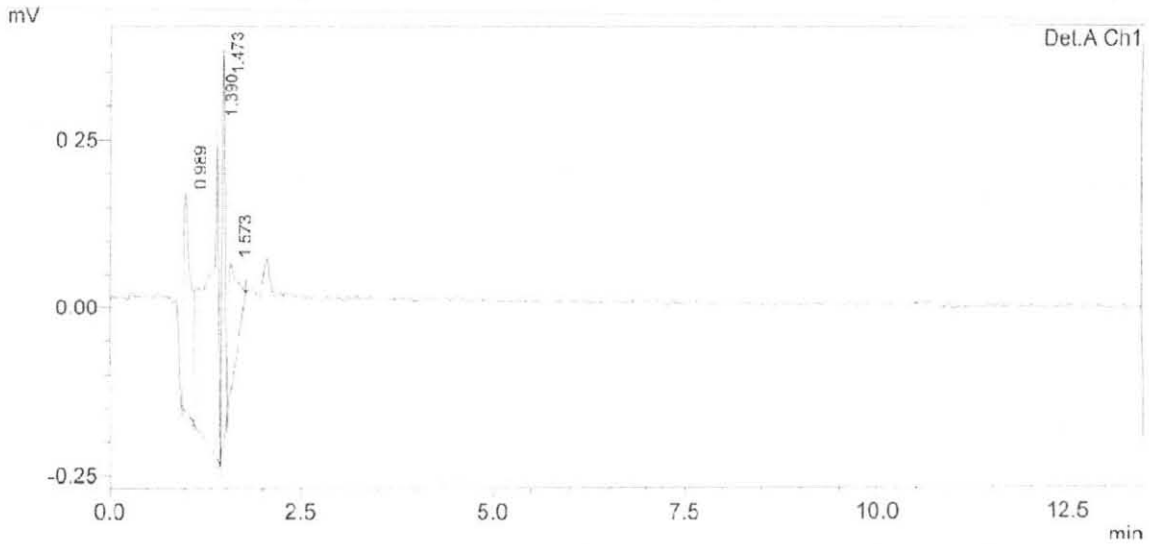
Raw young shoot of *O. abyssinica* (β-carotene peak observed at 10 min)



Cooked young shoot of *O. abyssinica* (β-carotene peak not observed at 10 minutes)



Raw *D. preahensilis* tuber (β-carotene peak not observed at 10 min)



Cooked *D. preahensilis* tuber (β-carotene peak not observed)

Annex 7.

Addis Ababa University Center for Food Science and Nutrition

Semi-structured questionnaire to assess household preparation methods of selected WEPs

0.1 Date |__|__|/|__|__|/2006(□□□ □□)

0.2 Enumerator Name:/ □□□□ □□□□ □□_____Signature/□□□/_____

0.3 Region /□□□ = B/G/□□□□□ □□□

0.3 Zone/□□= Kemash /□□□ **0.5 Woreda/**□□□:=----------

0.6 Kebele/□□□=----------

0.7 HH No----------

SEC 1: household WEPs preparation questionnaire/□□□□ □□□□□□		
Please ask all questions about food preparation methods write the responses given in the space provided for		
101.	Name of household head.....	
102	Name of wife_____	Age of wife |__|__|
106.	Are there different wild edible plants in your locality?	1= Yes/□□ / 0 = No/□□□□□/

107.	Have you ever used one of these weps as a Food? (circle numbers if used)	1= Echa (*Dioscorea praehensilis Benth*) 2= Kima (*Portulaca oleracia*) 3= Qenqetse (*Abelmoschus esculentus* (L.)) 4= Eta (*Oxytenathera abyssinicica*)
109.	How far are these weps from your home?	1= Echa _____hr/ min 2= Kima _____hr/ min 3= Qenqetse_____hr/ min 4= Eta or LLB____hr/ min
110.	Do you cultivate one of these vegetables at your garden or farm? If Yes, which one? (Circle number)	1= Echa (*Dioscorea praehensilis Benth*) 2= Kima (*Portulaca oleracia*) 3= Qenqetse (*Abelmoschus esculentus* (L.)) 4= Eta (*Oxytenathera abyssinicica*)
111.	Who is responsible to collect these WEPs	1= household head 2= Wife 3= male children

112.	Which part of these WEPs is used for food?	1= Echa (*Dioscorea praehensilis Benth*) --- 2= Kima (*Portulaca oleracea*) _____ 3= Eta (*Oxytenanthera abyssinicica*) --- 5= Qenqtse
113.	Who is responsible to Prepare those Wild vegetables	1= household head 2= Wife 3= male children 4 = female children 5= others specify _____

SECTION 2: food preparation questionnaire

Please ask all questions and write the responses given in the space provided

114	Name of responsible person for preparing WEPs Name_____	Description of detailed preparation methods

115	How do you prepare 1= Echa (*Dioscorea praehensilis Benth*)?	---------- ---------- ---------- ---
116	How do you prepare 2= Kima (*Portulaca oleracia*)?	---------- ---------- ----------
117	How do you prepare 3= Qenqetse (*Abelmoschus esculentus* (L.))?	---------- ----------
118	How do you prepare 4= Eta (*Oxytenathera abyssinicica*)?	---------- ----------

SECTION 4- WAYS OF PRESERVING WEPS BY THE COMMUNITY

401 Please describe how the WEPs are preserved by the respondents

	How do you preserve 1= Echa (*Dioscorea praehensilis Benth*)?	
120	How do you preserve 2= bella (*Portulaca oleracea*)?	
121	How do you preserve 3= Qenqetse (*Abelmoschus eculentus* (L.))?	
122	How do you preserve 4=Enta (*O. abyssinica*)?	

Remarks

_____

_____

_____

_____

Thank you for participating!