INFLUENCE OF HEATING AND SOAKING TREATMENTS ON PROXIMATE, MINERAL AND OXALATE COMPOSITION OF AMOCHI (*Arisaema schimperianum schott*)

M.Sc. THESIS

BY

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ARBA MINCH, ETHIOPIA

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A THESIS SUBMITTED TO THE DEPARTMENT OF HORTICULTURE, COLLEGE OF AGRICULTURAL SCIENCES, SCHOOL OF GRADUATE STUDIES, ARBA MINCH UNIVERSITY

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DECLARATION

I hereby declare that this MSc thesis is my original work and has not been presented for a degree in any other university, and all sources of material used for this thesis have been duly acknowledged.

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Signature:

Date: June, 04/2019

APPROVAL SHEET

This is to certify that the thesis entitled "Influence of Heating and Soaking Treatments on Proximate, Mineral and Oxalate Composition of Amochi (*Arisaema schimperianum schott*)**"** submitted in partial fulfillment of the requirements for the Masters Science Degree in **Post-Harvest Management,** the graduate program of the Department of **Horticulture,** and has been carried out by **Halabo Hazo**, under our supervision. Therefore we recommend that the student has fulfilled the requirements and hence hereby can submit the thesis to the Department for defense.

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Name of principal advisor	Signature	Date
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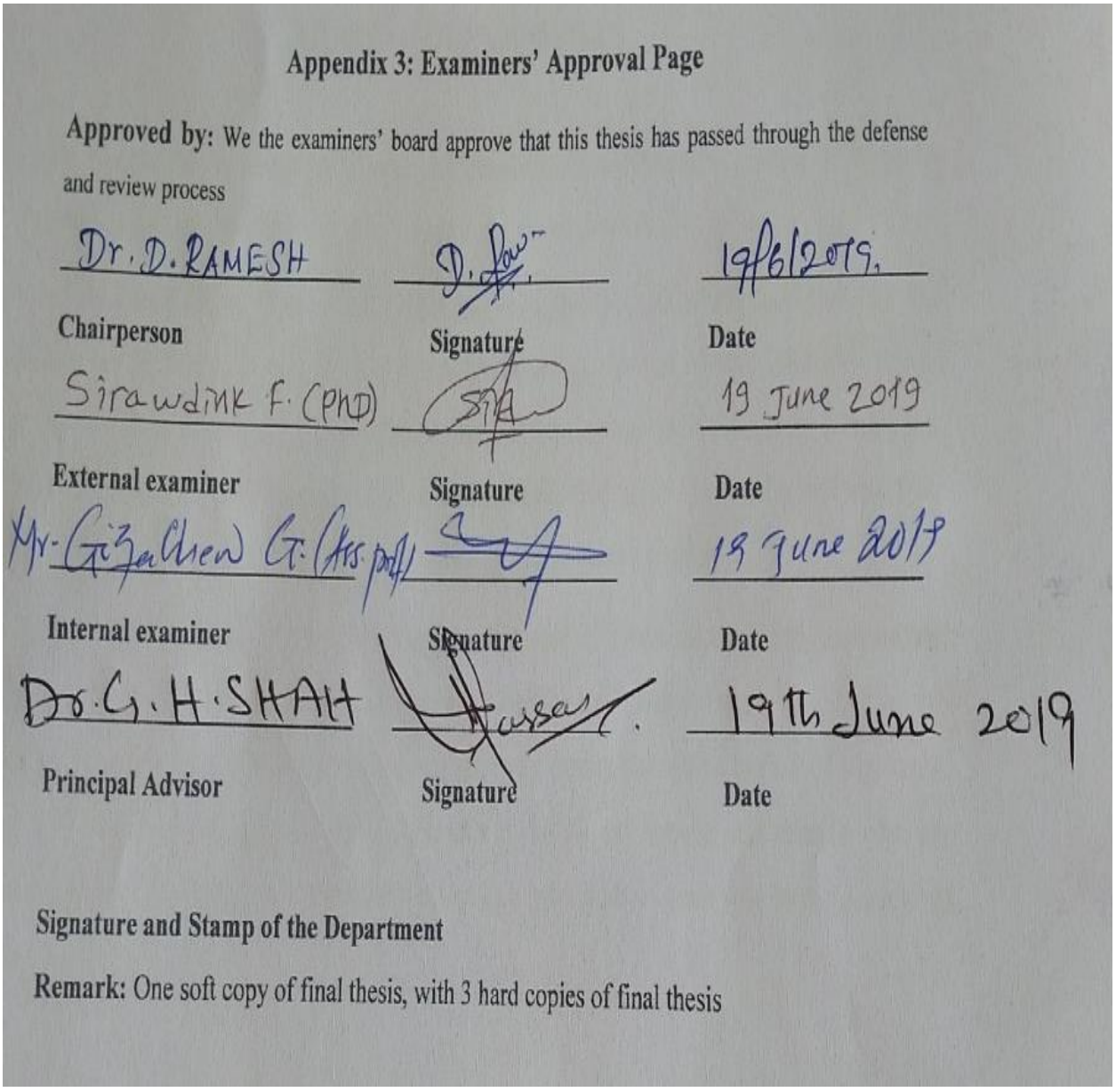
Name of co-advisor	Signature	Date

EXAMINARES BOARD APPROVAL SHEET



Appendix 3: Examiners' Approval Page

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ACRONOMYS AND ABBREVIATIONS

AAS	Atomic Absorption Spectrophotometer
ANOVA	Analysis of Variance
AOAC	Association Organization of Analytical Chemist
ATP	Adenine Triphosphate
CRD	Completely Randomized Design
CV	Coefficient of Variance
DPPH	Di phenyl Picry Hydrazyl
FAO	Food and Agriculture Organization
FW	Fresh Weight
GRAS	Generally Recognized as Safe
HPLC	High Performance Liquid Chromatography
LC	Liquid Chromatography
LSD	Least Significant Difference
pH	Power of Hydrogen
SAS	Statistical Analysis Software
USA	United States of America
UV	Ultra-Violete

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ABSTRACT

Amochi (Arisaema schimperianum schott) is herbaceous tuber crop belonging to the family Araceae, sub family Aroideae. The tuber is consumed as an alternate food in some areas of Ethiopia especially in food shortage season. Investigation of the effect of heating and soaking on proximate, mineral and anti-nutrient (oxalate) composite content in processed and unprocessed on Amochi was the goal of study. Amochi has high content of oxalate, thus the presence of oxalate, which bind the essential minerals like calcium, magnesium, iron and zinc. It also forms needle like raphides of oxalate crystals that responds the food leads to acridity, irritation, inflammation and burning sensation followed by swelling of hands, mouth, lips and throat as major causes for the health-related problems. Oxalate, proximate and mineral of raw and processed Amochi were evaluated with a design of factorial completed randomized design. Results revealed that heating and soaking combination significantly ($P<0.05$) influenced the proximate composition, mineral composition and oxalate content. The mean values of the proximate composition of unprocessed Amochi observed in crude protein 0.54%, crude fat 0.11%, ash 1.34%, carbohydrate 65.45% , moisture 32.39% and crude fiber 0.59%. Oxalate contents observed in unprocessed Amochi is the major hindrance for safe consumption. It was reduced 72.39 percent in boiled Amochi after soaked in low pH (2.01) in lemon juice. However, Amochi is richer in most of the minerals than many other root and tuber crops. Both unprocessed and processed Amochi tuber is comparable to many other root and tuber crops as a source of carbohydrates. It can be concluded that heat treatment included boiling after soaking in low pH solvent like in lemon juice pH value of (2.01) can be very helpful in reducing the level of anti-nutritional factor (oxalate) in Amochi. The quantity of Amochi to be consumed daily should not exceed the recommended limits of oxalate (50 to 100mg/100g oxalate for 2500 Kcal/day). Keeping these levels as a base the consumption can be worked out taking into consideration oxalate content of 268 mg/100g in Amochi treated with lemon juice after boiling. Furthermore studies need to be taken by various researchers, organizations or universities for studying on anti-nutritional factors such as (phytate & tannin) content, physico-chemical composition and processing technologies which can lead for more advantage use of the produce.

Key words: Amochi tuber, *Arisaema schimperianum schott*, heating techniques, oxalate content, proximate composition, selected minerals, soaking solutions, processing effect.

1. INTRODUCTION

1.1. Background of the Study

Amochi (*Arisaema schimperianum schott)* is herbaceous tuber crop that belongs to the family Araceae and sub family Aroideae. There are 105 genera and over 2000 species of the family found in all climatic regions of the world, but mainly in tropical or subtropical (Edwards *et al.* 1997 and Hiroyuki *et al.* 1998).

There are several edible tubers or stems such as taro (*Colocasia*), giant taro (*Alocasia*), Tania or yautia (*Xanthosoma*), Elephant foot yam (*Amorphophallus*), Swamp taro (*Cyrtosperma*) Amochi (*Arisaema*) as reported by FAO (1990). Aroids are tuber or underground stem bearing plants belonging to the family Araceae (Edwards *et al*., 1997; Turner and Szczawinski 1991). It is well adapted to wet climates and can give good yields in waterlogged or swampy soils. They provide important plant foods for many indigenous people of the tropics and subtropics. However, some members of this family are poisonous containing alkaloids and other toxins.

According to Kletter and Kriechbaum, (2001) distribution of Amochi is found in the Himalayas from Eastern Afghanistan to Bhutan, in South-eastern Tibet and Western China (Sichuan, Yunnan); 1800-4500m. In addition, the species occurs in Southern Arabia (Oman, Yemen and Saudi Arabia) and even in North Eastern Africa (Ethiopia).

As reported by Edwards *et al.*, (1997) the genera growing naturally in Ethiopia are members of three different subfamilies: Lasioideae, Aroideae and Pistoideae. The taxa indigenous to Ethiopia are found in seven genera with 15 species; there are four or more cultivated and/or ornamental taxa.

Andargachew *et al.*, (2007) reported that the 12-15 types of Amochi identified in the study area. Local name of Amochi type represents morphologically distinct Amochi type. Amochi types differ with respect to morphological characters such as leaflet number and color, stem color, plant height, flower color, maturity period, vigor and relative level of irritability to the skin and mouth. But full analysis of these differences were not reported yet.

Amochi is easily recognized by the charming bright yellow spathes, which are smaller compared to other species of the genus. The length of the yellow spathe blade is up to 3 cm; usually it is purplish inside at the base. The tube of spathe is swollen, the blade is almost erect and acute with

an ellipsoid appendix. The plant is bisexual. Female and male flowers are born on the same plant and have a 1 to 2 centimeter long spadix. Female basal part shows ovaries which is greenish in color. The male basal part is slightly different in color it is slightly yellow colored and is 3 to 7 centimeter long and up to 3 millimeter in thickness with yellowish green short appendix. Flowers have 2 anthers which are 2-loculed. The main flowering time is June and July. The fruiting spike, set on an erect stalk, bears red berries containing a few seeds which are pale yellow in color and are 2 to 2.5 millimeter long (Kletter and Kriechbaum, 2001).

The leaves are pedate (divided like the fingers of a hand, with the clefted lateral lobes). The central leaflet is narrowly oblenceolate and finely acuminate sessile, with a cuneate base. The above ground part sprouts from a globose, bulb-like corm, which is a short, swollen stem. It grows underground in a vertical position within about 10 to 20 centimeter of the surface (Kletter and Kriechbaum, 2001). Amochi is cultivated mainly for its tuber. Like yam, cocoyam, elephant foot yam and taro, Amochi tubers have also dual agricultural function. It is used as source of food and as a planting material (Craufurd *et al.,* 2006).

Tuber crops refer to any growing plant that stores edible material in subterranean root, corm and tuber. The nutritional value of roots and tubers lies in their potentially able to provide one of the cheapest sources of dietary energy in the form of carbohydrates in developing countries (Ugwu 2009).

However high yields of roots and tubers give more energy per land unit per day compared to cereal grains (FAO, 1990). The contribution of roots and tubers to the energy supply in different populations varies with the country. The relative importance of these crops is evident through their annual global production which is approximately 836 million tones. African regions produced 33% of the global production of roots and tubers. A number of species and varieties are consumed but cassava, potatoes, and sweet potatoes consist of 90% global production of root and tuber crops (Food and Agriculture Organization Corporate Statistical Database, 2003).

As Tsegaye and Struik, (2002) reported that Amochi has been used as a food crop for more than 40 years, in two neighboring villages Dokomesho and Delbansa, which belong to Chencha and Dita, respectively located at Gamo zones of Southern Ethiopia. Elisabeth and Hildebr, (2003) recognized that it has a vital role in supporting the population as source of food. They reported that there are various ways of preparing Amochi for food based in its growing areas of the

country. At Dita Woreda, Gamo zone of southern Ethiopia, the Amochi harvesting is carried out by men, while the women perform all postharvest handling operations till it reaches to the dish as a family meal. Higher caloric intake of 22 to 40 % carbohydrate consumption contributes the human diets for local population of Gamo zone, Southern Ethiopia diets most of comes from root and tuber crops (Cordain *et al.*, 2000).

Reddy *et al.*, (2014) reported that healthful sources of carbohydrates include whole root and tuber crops and dietary fiber, which comprise a variety of bioactive components. These components include resistant starches (such as Glucomannan) and micronutrients (such as magnesium, folate, vitamin B6 and vitamin E), which are beneficial for health when consumed in sufficient amounts. In the same studies they stated that human body is unable to digest many raw root and tubers effectively, or at all, without processing before consumption. This includes root and tuber crops like cassava, taro, sweet potato, potato, yam, elephant foot yam and Amochi. These starchy foods need to be processed to make them safe for consumption. Root and tuber crops like cassava, sweet potato, potato taro, yam and Amochi need processing like peeling or grating and soaking before cooking to reduce the anti-nutrient content to make it safe for consumption.

In Ethiopia uses of Amochi for food purpose is an established practice in Amochi growing area. Dita, Chencha, Bonke, Doko, Dara, kemba and Sura are some of the main growing areas for this tuber crops. Thus a major alternate food for the local population especially during the drought season. However, the consumers have been experiencing some problems like stomach pain, night blindness, and irritation of lips, hands, skin and throat once the Amochi tubers are consumed. The present investigations was undertaken to address these problems in an effort to make the Amochi plant as a safe food for the local population.

1.2. Statement of the Problem

Dita area of Gamo zone is a hilly area which is generally affected by drought conditions. Such in area of insufficient food production the situation becomes more adverse as and when there is drought. Thus the local population has no available food source. Under such condition Amochi tubers are generally consider as major alternate food source for the local population.

A large area in Ethiopia falls under rough and inaccessible terrain. Dita is a sub-administrative zone of Gamo which has rough terrain. The population makes their livelihood by rearing cattle, growing agricultural crops like cereals (barley and wheat), legumes (bean, pea and haricot bean), and root crops (sweet potato, potato, taro and yam). The production of these crops are much lower than the food requirement of the area. The cultivated crops provide food to population for a short period of the year, but in most of the months especially from September to November there is acute food shortage. For their survival the local population has explored the use of wild tuber crop (Amochi) growing in the area for their food during food scarcity period. However, despite the fact that the Amochi tuber satisfies hunger, most people experience some discomforts after consumption such as lips and throat irritation, kidney failure, stomach disturbance, night blindness, edema and other health problems. Health problems caused after consuming Amochi is considered to be of the same nature.

Earlier researchers reported the presence of high content of oxalate in Amochi foods, which bind the essential minerals like calcium, magnesium, iron and zinc. It also forms needle like raphides of calcium oxalate crystals, that responds the food to acridity, irritation, inflammation and burning sensation followed by swelling of hands, mouth, lips and throat irritation as major causes for the health related problems (Onwuka, 2005).

Therefore, this study was initiated to investigate the proximate composition and anti-nutrient (oxalate) intake for safe consumption in the Amochi tuber. If these problems are overcome, Amochi can provide a suitable alternate food for the area as these tubers do not need heavy investment for cultivation. The present study was conducted with an objective to find the proximate composition of Amochi so as to assess its nutritional values and possible potential health hazardous components and developing a simple processing techniques to reduce the effect of oxalate.

1.3. Objective of the Study

The main objective of this study is to investigate the effect of heating and soaking treatments on proximate, minerals and anti-nutrient (oxalate) composition of raw and processed Amochi tuber.

1.3.1. Specific objectives

To find out the effect of heating and soaking treatments on the proximate composition of Amochi, to find out the effect of heating and soaking treatments on the mineral content of Amochi and to find out the effect of heating and soaking treatments on the oxalate content of Amochi.

1.4. Hypothesis of the Study

1.4.1. Null hypothesis

There will be no significant difference in proximate composition and oxalate level between the unprocessed and processed Amochi products.

1.4.2. Alternate hypothesis

There will be significant difference in proximate composition and oxalate level between the unprocessed and processed Amochi products.

1.5. Significance of the Study

The study has vital importance to overcome the health related problems being faced by the consumers of Amochi. Besides proposing a processing technique of reducing anti-nutritional factor (oxalate) in the Amochi products, the results will also help to measure safe quantities to be used for daily diets.

It will also play a significant role in inculcating the future trend of Amochi cultivation in hilly and rough terrains which do not grow adequate cereal grains because of lack of irrigations and other factors. In general, the study is worthwhile because the benefits of its outcomes are manifold: farmers and consumers can utilize the information generated to take advantage of promised processing techniques, policy makers can utilize the information to decide food safety and nutrition strategy, researchers and extension agents can utilize the findings of the research for future research and extension.

2. LITERATURE REVIEW

2.1. Amochi

Amochi (*Arisaema schimperianum*) is herbaceous tuber crop that the tender and sheath like organs on the base of the plant (cataphylls) are pale with a brownish purple tinge. Usually the inflorescence is accompanied by one or two green leaves. The overlapping bases of the leaf stalks form a ‘’pseudo stem’’ which is green. It is a storage organ enabling the plant to survive under unfavorable conditions. After the completion of full life cycle, the plant parts which are above the ground die while their contents withdraw partly into the new underground storage organs (Kletter and Kriechbaum, 2001).

2.1.1. Propagation of Amochi

Propagation of Amochi can be done from seed, offsets, or by cuttings, but seed is the most used method. For its propagation one require seeds either from a monocious species or a diocious species. Depending on the species mostly seed ripen from early fall to late winter. Ripe seed are red in color but green seeds can be picked if the entire seed head is harvested. After the seeds are harvested, they should be cleaned to remove the pulp from the seeds as pulp contains a germination inhibitor (http://www.plantdelights.com).

Amochi seed can be planted immediately after cleaning. It usually sprout within 4- 6 weeks and grow for up to 2-4 months. After this the plants go slowly into dormancy. Some species grow directly from seed to small corms, known as proto corms. These proto corms don't produce foliage until after dormancy. These Amochi seedlings can be kept in dormancy until winter or planted immediately. They again re-sprout after a cold period (http://www.plantdelights.com).

2.1.2. Harvesting and processing of Amochi

Well-grown tubers are dug out during cultivation. The top part of the tuber attached to the stem and carrying roots is cut-off from the remaining part of the tuber and buried in the soil as a propagation material for the next season while the bottom part is harvested for consumption (Andargachew *et al.,* 2006)

Harvested Amochi is usually taken to the river for washing. Then the tubers are taken one at a time and crushed between milling stones. The crushed Amochi is then kept in baskets made of bamboo, which are full of little pores to allow the liquid part to leach out. Some households use the leach-out liquid to boil forage. The solid part then is re-crushed and can be kept up to two

years in airtight condition, usually buried in the ground. The crushed Amochi can be consumed from the first day depending on the availability of food (Andargachew *et al.,* 2007).

Upon contact, Amochi is irritating to the skin and mouth when not properly processed. The irritation level decreases with the duration of storage. The types of food made from Amochi include forage and bread. It can also be mixed with barley, wheat and maize flour to make different types of dishes. (Andargachew *et al.,* 2006)

Also, with the same study Andargachew *et al.,* (2006) reported that the relative contribution of major farm products to total household consumption over the entire year Amochi accounted 9 and 4 percent of the food crop in Dokomesho and Delbansa respectively. In both areas (enset) accounted for the largest share of crop produce consumed as a food followed by cereals, grain and legumes.

Andargachew *et al., (*2006) also reported that Amochi tuber crop which can grow throughout the country in altitude range 1700 to 3200 meter above sea level can serve as an alternative and off-season food source to people who are suffer with food shortage. The one season yield of Amochi tuber with in a season is up to 12 tons per hectare.

Amochi emerges from the remnants of seed tubers left in the soil. Therefore, farmers do not plant Amochi each season unless they are introducing it to a new agricultural land. It grows by residual moisture, during the dry season after the harvest of the main season crops and harvested at the beginning of the wet season when the stored food reserve from the main season crops nearly are depleted (Andargachew *et al.,* (2007).

Ross *et al*. (1999) was reported that the tuber crops contain moderate to high level of soluble oxalates in the tubers. Fortunately, processing tubers by either boiling or steaming before consumption reduces the oxalate levels. *C. Esculenta* has the highest oxalate content and is used in making soup in the Eastern part of Nigeria while the *Xanthosoma spp.,* which has the lowest, oxalate content, is consumed in both raw and cooked forms (Sangketkit *et al.,* 2001).

Unprocessed Amochi is irritating in contact to hands and mouth, and Amochi growers are not well aware how to reduce the level of irritation by traditional food processing and use of less irritating types. Consecutive food shortage due to severe moisture stress condition in Southern Ethiopia forced the people to give more attention to drought tolerant tuber crops like enset and to

use off-season crops as Amochi (Tsegaye and Struik, 2002). In their further studies they reported Amochi is used as a food source crop for more than 40 years, in two neighboring villages Dokomesho & Delbansa, belongs to Chencha and Dita Woreda respectively, which is sub-administrative zones of Gamo, Southern Ethiopia.

2.2. Use of Amochi in Traditional and Folk Medicine

Since long various species of *Arisaema* are used by various tribes and communities for medical and food purpose as reported by Meuninck, (1942). *Arisaema triphyllum* roots are being used as food by Indians after drying and deactivating the caustic calcium oxalate. Its dried roots are traditionally used to treat respiratory problems; asthma, bronchitis, cold, cough, and laryngitis. For ringworm, sores, boils and abscesses externally poultice root is used as a wash. Roots infusion is used as a contraceptive for temporary sterility by Iroquois women (R. Hu *et al*. 2009).

Nile and Park (2014) reported that the methanolic extract of *A. tortuosum* tuber (1 mg/mL) has observed antioxidant activity against DPPH, ABTS and FRAP assays and *A. tortuosum* tuber was found to possess in vitro tumor growth inhibition on HeLa cancer cells. *A. tortuosum* tuber was found to possess anti-inflammatory effects in diene conjugate and β glucuronidase assays.

In Kedarnath valley of western Himalaya, *Arisaema wallichianum* tuber paste is applied externally for treating erysipelas and scabies by the traditional healthcare system practitioner (Bhatt, and Vashishtha, 2008). The rhizomes or tubers *of A. asperatum, A. heterophyllum, A. calcareum, A. serratum, and A. amurense* are used as analgesic, pesticide, and antitumor agents in traditional Chinese medicine (Anonymous, 2005).

A Chinese herbal traditional medicine system uses *A. cumbile* for treating neurological and dementia symptoms and also the rhizomes of *Arisaema leschenaulti* are eaten as boiled vegetables (Sahoo *et al*., 2010). Different parts of *Arisaema leschenaultii* are used in Ayurveda for the treatment of eczema, gonorrhea, urinary diseases, fistula, colitis, piles, hemorrhoids, syphilis, roundworm, and sinus (Kirtikar and Basu, 1985).

Abbasi *et al., (*2010) reported that the treatment of asthma, the powder of *Arisaema speciosum* fresh tubers are roasted in an air tight mud pot and are taken orally along with grapes at bed time. Fresh tuber paste is applied over infected skin and boils. Fruit grain is swallowed once daily during gas trouble.

Arisaema jacquemontii herb has been reported by Pandey, (2006) to treat toothache, stomach problems, fever, swelling, scabies, chest infection, anthelmintic, throat problems and in uterus and menstrual disorders in Tibetan therapy system in Nepal.

In India, the juice of the tubers of *Arisaema jacquemontii* is applied to treat skin diseases such as ringworm (Kletter, and Kriechbaum, 2001). Paste of rhizome grounded with edible oil is used to treat skin problems such as blisters and pimples and for regaining muscular strength (Sudan *et al.,* 2014).

Decoction of fruits is given orally as antidotes of poisonous mushrooms and in snake bite (Begum *et al.,* 2014). The researchers further reported that *Arisaema jacquemontii* fruit has insecticide and antipyretic properties. It is used in very small quantity during meal for relieving fever. Rhizome decoction of plant is given to cure menstrual related disorder by ethnic people of Western Nepal (Malla *et al.,* 2015).

Fresh tuber of the plant is used in Uttrakhand state of India for treatment of vomiting and in snake bite (Kala, 2015). According to patent filed by Hanan Elraz, *Arisaema concinnum* extract is used as a component in the preparation of composition for the treatment of cancer (http://www.google.com/patents). Tubers are used as de-worming for cattle and as insect repellent. Underground parts, tubers and rhizomes of *Arisaema concinnum* used during famines (Mishra, 1985).

Arisaema flavum root and stem paste is externally applied on skin for treating skin infection in ethno veterinary practice. It also acts as insecticide (Begum *et al*., 2014). It is a famine food, eaten during periods of crop failure or famine in the Konso special Woreda, where it is endemic. The dried powder is mixed with water and cooked like maize for 30 minutes for eating. It is also used as antispasmodic and expectorant (Guinand and Lemessa, 2009). The crushed tubers paste is applied for treating foot and mouth diseases in cattle (Kumar *et al*., 2009).

Tubers are useful for toothache, stomach ache and chest infection (Lama *et al.,* 2001). Rhizome and red fruits are chewed raw to treat in case of any poison by ethnic people of Nepal which causes numbness of tongue (Malla *et al.,* 2015). The tuber of plant is used for the treatment of chronic tracheid's bronchitis, tetanus, epilepsy, skin diseases and as insecticide in Manali wildlife sanctuary of North western Himalaya (Rana and Samant, 2011).

Major uses of *Arisaema* are broadly divided into four parts: to expel out large amounts of phlegm, to clear phlegm-mist from the heart orifices, to remove phlegm-obstruction of the meridians (especially from Luo vessels), and to dry accumulation of phlegm-damp in the upper limbs or throughout the body (http://www.itmonline.org).

For removing extra phlegm, *Arisaema* is often accompanied by chih-shih (*zhishi*), Piniella and citrus (*chenpi*), hoelen (*fuling*); for clearing orifices, it is accompanied by other herbs of the same family (*Araceae*), namely acorus (*shichangpu*) and typhonium (*baifuzi*), as well as by certain unrelated materials, especially polygala (*yuanzhi*), earthworm (*dilong*), gastrodia (*tianma*), and silkworm (*baijiangcan*) (http://www.itmonline.org).

Arisaema, like gastrodia and earthworm, is said to clear phlegm and "eliminate wind" to explain their applications for treating, strokes, convulsions, and other "wind-phlegm" related disorders. In modern practice, *Arisaema* is included in preparations for Alzheimer's disease, for post-stroke syndrome due to phlegm accumulation; other applications include advanced (severe) arthritis, headaches (related to phlegm obstruction as one of the contributing factors), carpal-tunnel syndrome (especially in persons who are overweight), and bronchitis with sputum production (http://www.itmonline.org).

Arisaema is a time-honored Chinese herb, and is frequently used to treat hemiplegia, Bell's palsy, convulsions in children, epilepsy, tetanus, carbuncle, snake bites, and similar diseases. Bile processed *Arisaema* is used to treat the retention of heat-phlegm in the lung of children, infantile convulsion and tic of limbs. It is reported that in cervical cancer, cervical canals or vaginal suppositories made of fresh *Arisaema* is effective. Boiled leaves of *Arisaema consanguineum* are eaten as vegetables in Nepal. The tubers of many species of *Arisaema* are used for different variety of medicinal purposes. *Arisaema consanguineum* is traditionally used to treat, epilepsy, coughs and rheumatism (http://www.kew.org/science-conservation).

2.3. Chemical Composition of Amochi

2.3.1. Proximate composition

Root and tuber crops have very high yield potential but low protein, mineral and vitamin content compared to cereals (Bradbury and Holloway 1988; Bareja 2010). Roots and tubers are deficient in most other vitamins and minerals but contain significant amounts of dietary fiber (FAO,

1990). Similar to other crops, nutritional value of roots and tubers varies with variety, location, soil type, and agricultural practices, among others (Chandrasekhar and Josheph 2016).

Dutta, (1909) reported that some Amochi species are rich in nitrogen and the amount of starch present is as high as in many cereals. *Arisaema concinnum* chemical composition *of* 8.45 % moisture, 7.68 % albuminoids, 1.43 % fat, 65.94 % carbohydrates, 8.90 % fiber, 7.60 % ash, 1.23 % nitrogen, 1.17 % calcium and 1.03 % silica.

As reported by Rastogi and Mehrotra, (1979) *Arisaema* species tubers shows presence of carbohydrates, albuminoids, fat, nitrogen, calcium etc. Main chemical constituents present in *Arisaema flavum* are alanine, ariseminone, asparagine, cysteine, glycine, norvaline, & ornithine. Fatty acids content like 1-3-phenyltridecanoic acid (Kletter and Kriechbaum, 2001).

Triterpenoids content like α-amyrin, β-amyrin, lup-20 (29)-en-3β ol, lup-20(29)-en-3β-yl acetate. Sterol content like β-sitosterol, β-setosteryl galactoside. And lectin *Arisaema flavum* lectin has a neutral sugar content of 2.8% (Ahmad *et al.,* 2003).

The seed of *Arisaema* were found to contain 1-3-phenyltridecanoic acid (ω-phenyalkanoic acid) among other saturated and unsaturated straight chain fatty acids. (Kletter and Kriechbaum, 2001). It has been reported to contain four triterpenoids α-amyrin, β-amyrin, lup-20(29)-en-3β-ol, lup-20(29)-en-3β-yl acetate, two sterols β-sitosterol, β-setosteryl galactoside (Ahmad *et al.,* 2003).

According to Lewu *et al.,* (2010) root and tuber crops (cocoyam and potato) are high in carbohydrate content of 86.53% and 83.21% respectively. Also it is reported that the carbohydrate content of root and tuber crops are generally rich in carbohydrates (Eka 1998), hence, their high caloric values. The caloric values obtained for these two crops are more than that of cassava, Irish potato, sweet potato, yam and taro (Bradbury and Holloway 1988; Souci *et al*. 1994).

The increase in moisture content during cooking is due to softening of the tissue of tuber crops, thereby increasing the water absorption and water-retention capacity of the tubers due to increased permeability of the cell membrane to water (Mbajunwa 1995).

As Bradbury and Holloway (1988), showed that the moisture content ranged from 63 to 85% on fresh weight bass in fresh taro tuber whereas 76.94% for fresh potato was reported by Yildrim

and Tokus, (2005). According to Lewu *et al.,* (2010) the moisture contents reported for fresh cocoyam and potato 66.62% and 81.53% respectively. In their further comparison studies, of processed potato contained more moisture 80.72% than cocoyam 68.10% on dry weight basis.

Fiber has long history, its term originating with Hipsley (1953), who coined dietary fiber as a non-digestible constituents making up the plant cell wall and further its definition has seen several revisions.

As stated by Trowell *et al.* (1985) and Guillon and Champ, (2000) the physico-chemical properties of fiber can be manipulated through treatments: chemical, enzymatic, mechanical (grinding), thermal or thermos mechanical (extrusion, cooked-extrusion, and controlled instantaneous decompression) to improve their functionality. For example, mechanical energy can also have profound effects on polysaccharides (Poutanen *et al.,* 1998).

According to Spiller (1986) and Roehrig (1988) grinding may affect the hydration properties, in particular, the kinetics of water uptake as the result of the increase of surface area, the fibers hydrate more rapidly. In wheat bran it has been found that thermal treatments (boiling, cooking or roasting) originate an increase of total fiber that is not due to new synthesis, but rather to the formation of crude fiber-protein complexes that are resistant to heating and are quantified as dietary crude fiber (Caprez *et al.,* 1986).

Processing required to make some root and tuber crops, vegetables and legumes suitable for eating causes a decrease of several components of the fiber. For example, during cooking of lentils previously dipped, the quantity of fiber diminishes, fundamentally due to great decrease in hemicelluloses (Vidal-Valverde and Frias 1991; Vidal-Valverde *et al.,* 1992).

As reported by Tatjana *et al.,* (2002), the solubilization of polysaccharides resulted in decreased total fiber content mainly due to loss of soluble fiber, during thermal processing of kidney beans. The effect of thermal treatment (including extrusion cooking, boiling and frying) on the dietary crude fiber composition of cereals and potato samples were studied by Varo *et al.,* (1983) at 8 laboratories using different analytical methods. They reported that heat treated potato samples contained more water insoluble dietary fiber and less starch than raw samples. No changes were observed in the amounts of dietary fibers and starch in the extruded samples.

According to FAO, (1999) the global contribution of proteins from roots and tubers in the diet is less than 3%. However, in African countries, this contribution may vary from 5 to 15%. The chemical composition of Amochi was not analyzed before, but in the area growing roots and tuber crops including taro, yam, cocoyam, potato are reported as generally low in protein; hence, food products from these crops should be supplemented with other high-protein products for balanced nutrition Bradbury and Holloway, (1988). Processing like cooking and boiling resulted in more availability of protein. Cooking process leads to breakage of the tannin-protein complex thereby limiting the protein availability in food (Eka 1985).

The protein contents of roots and tuber crops are variable. In selected root and tuber crops (cocoyam, potato, cassava and yam) the protein content of roots and tubers is low ranging from 1 to 2% on a fresh weight (FAO, 1990), but potatoes and yams contain high amounts of proteins among other tubers. Debre and Brindza (1996) reported that the crude protein contents of fresh cocoyam 6.40 % and fresh potato 10. 34 percent, but after processing the protein content was found 8.96 % and 10.41 % for cocoyam and potato respectively.

Mbajunwa (1995) reported that the ash contents of cocoyam tuber has ranged from 3.65 to 4.09% and potato has ranged from 3.93 to 4.58 percent. In addition the research has reported that the potato tuber had significantly higher values whether cooked or uncooked than cocoyam tuber.

However, the ash levels in the two tubers were reduced in the course of the cooking, which could be attributed to the solubilization and leaching of nutrients into the processing water. According to Njoku and Ohia (2007) the ash content of three cocoyam cultivars in Nigeria ranged from 4.60 to 7.78 percent.

Mondy and Mueller (1977), reported that all root crops exhibit very low fat content. Similar reports were recorded by Onyeneho and Hettiarachchy, (1993) who reported that the crude fat content values ranging from 0.17 to 0.21% in six potato varieties.

The higher fat contents in the processed (cooked) food could possibly increase extractability of the more polar fat or fats that are bound to other macro constituents in the tissue. This does not pose a problem in crude fat, even when cooked (Lewu *et al.*, 2010).

2.3.2. Mineral composition

All the animal body requires seven minerals in relatively large amounts such as calcium, sodium, magnesium, potassium, phosphorous chlorine and sulphur. These are called major minerals. And at least seven in trace amount these are cobalt, copper, iodine, iron, manganese, molybdenum, and zinc. These are called minor minerals (Osborne & Voogt, 1978).

The minor minerals are not less important than the major ones, all are needed for good health. Instead, deficiency depends on the natural availability of the mineral: if the mineral is found in lots of foods, it's unlikely your intake will be low such as iodine, manganese and phosphorus are found in a wide variety of foods, so deficiency is rare. The recommended intake of major minerals like as calcium 800 mg/day, magnesium 300 mg/day, zinc 15 mg/day and iron 14 mg/day (Rutherford, 2007).

2.3.2.1. Calcium

Several researchers reported that a calcium is an essential mineral for human health, participating in the biological functions of several tissues (musculoskeletal, nervous and cardiac system, bones and teeth, and parathyroid gland). In addition, calcium may act as a cofactor in enzyme reactions (fatty acid oxidation, mitochondrial carrier for ATP, etc.) and it is involved in the maintenance of the mineral homeostasis and physiological performance in general (Theobald, 2005; Huskisson *et al*., 2007; Morgan, 2008; Williams, 2008).

The concentration of calcium in root and tuber food shows a wide range of variation. As a report of (http://www.anyvitamins.com/rda), data on the calcium content of foods are important and should be considered when recommending the daily intake of minerals, as the recommended daily allowance for these nutrients is set out in the wide range of 800 to 1300 mg/day.

An increase in calcium intake during pregnancy is recommended to prevent risk of pre-eclampsia (Peters *et al*., 2004). Several studies have shown an association between suboptimal calcium intake and osteoporosis, hypercholesterolemia and high blood pressure (Unal *et al*., 2007).

Recent reports of Morgan (2008) showed that the unequivocal role of calcium as a second messenger. With respect to disease prevention, calcium intake moderately reduces the risk of colon cancer (Pele *et al*., 2007; Peters *et al*., 2004).

As reported by Lewu *et al*., (2010) on the fresh weight of the average calcium content of 34.62 mg/100g and 15.29 mg/100g was recorded in fresh cocoyam and potato respectively, but it was observed 30.73 mg/100g and 22.77 mg/100g in cooked cocoyam and potato respectively.

Calcium levels undergo homeostatic controls to avoid an excessive accumulation in blood or tissues, there are a number of conditions that result in an excess of calcium within the body because of a failure in the control mechanisms: hypercalcaemia may occur as a result of either increased mobilization of calcium from bone, or increased tubular reabsorption or decreased glomerular filtration in the kidneys, and less frequently, as the result of an increase in the dietary intake (Theobald, 2005).

2.3.2.2. Magnesium

As Lewu *et al.,* (2010) reported that magnesium is a strongly present in the root and tuber crops and also stated a critical role in the maintenance of human health through the diet. In their further studies the content on fresh weight of 128.35 mg/100g and 145.49 mg/100g were observed in processed and fresh potato respectively, whereas it was observed 89.68 mg/100g and 114.89 mg/100g in processed and fresh cocoyam respectively.

According to (http://www.anyvitamins.com/rda.htm) the recommended daily intake of magnesium is 200 to 400 mg. This essential mineral acts as a calcium antagonist on vascular smooth muscle tone and on post-receptor insulin signaling. It has also been related to energy metabolism, release of neurotransmitters and endothelial cell functions (Bo and Pisu, 2008).

In addition, magnesium participates with muscle and nerve excitability, as a cofactor of up to 300 enzymes (Huskisson *et al.,* 2007). Magnesium deficiency is related to ageing and age related disorders, mainly as a consequence of deficient intake in the diet (Durlach *et al*., 1998; Killilea and Maier, 2008).

Recent findings of Bo and Pisu, (2008) stated that an increase in the intake of this mineral (Mg) helps to protect people from the incidence of chronic diseases such as diabetes, metabolic syndrome, hypertension and several cardiovascular conditions.

Low magnesium diet may contribute to insulin resistance, especially when this deficiency is combined with a high fructose diet. Moreover, reduced magnesium intake is linked to

inflammatory response as a result of modulation of the intracellular-calcium concentration (Ahokas *et al*., 2005; Rayssiguier *et al*., 2006).

As a report of Guerrero and Rodriguez (2005) the toxic effects of magnesium are not frequent, the most common side effects of an excessive intake of this mineral being headache, nausea, hypotension and unspecific bone and abdominal pain.

2.3.2.3. Iron

The iron in root and tuber crop foods origin is mostly present in the form of insoluble complexes of Fe^{3+} with phytic acid, phosphates, oxalates and carbonates. However, the bioavailability of the iron present in foods is less than 8% (Szefer and Grembecka, 2007).

Lewu *et al.*, (2010) reported that the iron content in fresh and processed root and tuber crops (cocoyam and potato). It was observed that the iron content of 9.08 mg/100g and 13.78 mg/100g in fresh and processed cocoyam, but it was observed in fresh and processed potato of 11.20 mg/100g and 9.95 mg/100g respectively.

The recommended intake of iron is 8 to 18 mg per day (http://www.anyvitamins.com/rda.htm). The major function of iron is related to the synthesis of haemoglobin and myoglobin (Huskisson *et al*., 2007; Guerrero and Rodriguez, 2005; Shenkin, 2008). It is also required for energy production. The first reason for iron deficiency is inadequate iron intake (Lukaski, 2004).

According to (Huskisson *et al*., 2007 and Guerrero and Rodriguez, 2005) severe iron deficiency resulted in hypochromic anemia. They reported also its toxic levels in the body may be a consequence of genetic or metabolic disorders, frequent blood transfusions or excessive intake. Thus an excess of iron over a long period could result in liver and heart damage, diabetes, and skin changes.

2.3.2.4. Zinc

Zinc is required for the structure and activity of more than 100 enzymes (Huskisson *et al*., 2007; Guerrero and Rodriguez, 2005; Shenkin, 2008). Also it require the synthesis of nucleic acids and proteins, for cellular differentiation, and for glucose use and insulin secretion (Lukaski, 2004). This mineral takes part in the zinc fingers associated with DNA, haemoglobin, myoglobin and cytochromes (Guerrero and Rodriguez, 2005; Shenkin, 2008).

The concentration of zinc in plant-based foods generally varies from 0.05 to 11.8 mg/100g. Recommended daily zinc consumption ranges from 8 to 11mg (Lukaski, 2004). The bioavailability of zinc is reduced by the presence of large amounts of other elements such as iron or copper (Shenkin, 2008).

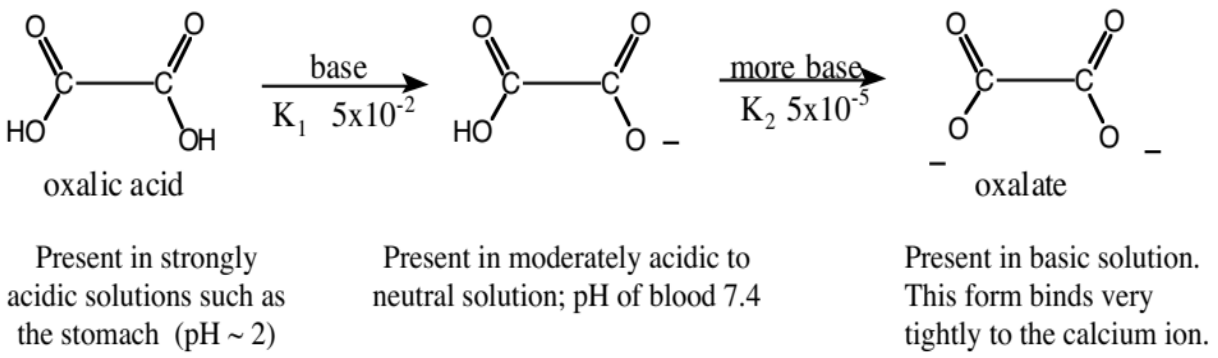
As reported by Lewu *et al*., (2010), the average zinc content of 2.39 mg/100g and 1.08 mg/100g was recorded in fresh cocoyam and potato respectively, but it was observed 2.52 mg/100g and 3.15 mg/100g in cooked cocoyam and potato respectively.

Zinc deficiency is relatively frequent and well characterized, and the absence of zinc is negatively affects the immune system efficacy, and the sensibility of taste and smell senses, and impairs DNA synthesis (Guerrero and Rodriguez, 2005; Shenkin, 2008).

Shenkin, (2008) reported that zinc toxicity has both acute and chronic effects. It has also been described that zinc deficiency produces hair loss and hypochromic anemia. Intakes of 150 to 450 mg/day over an extended period of time have been associated with poor copper levels, altered iron and immune functions, and reduced levels of high density lipoproteins (Guerrero and Rodriguez, 2005; Hamilton *et al*., 2001).

2.4. Oxalate

Oxalate is the interchangeable word of oxalic acid it was first time discovered by Scheele, in 1776, and it is found in the organic as well as in the inorganic kingdoms (Figure 1). Oxalate is a molecule that has a pivotal role in preventing the absorption of calcium for mitigating the kidney stones in humans. Oxalate in food is either soluble or insoluble. Oxalates can be found in relatively small amounts in many plants. Oxalate rich plants are usually minor components in human diets but are sometimes important in seasonal diets in certain areas of the world. (Noonan & Savage, 1999).



Source: http://www.nal.usda.gov/fnic/foodcomp/Data/Other/oxalic.html

Figure 1. Interchangeable name of oxalate and oxalic acid.

Savage *et al.* (2000) reported that oxalic acid forms water-soluble salts with Na^+, K^+ and ions, it can also form insoluble oxalates by binding with Ca^{2+}, Fe^{2+} and Mg^{2+} and rendering these minerals unavailable. The presence of oxalate in food impairs the absorption of most metals. So, the consumption of oxalate rich foods could further aggravate the already existing deficiency of metals such as calcium and iron (FAO, 2003).

Yadav and Sehgal (2003) reported that oxalates are widely found in many plant species and occur as end products of metabolism both in soluble and insoluble forms. The oxalate content of foods can vary depending on the variety, growth, season, soil conditions, time of harvest and many other factors. Plant foods are considered as the major dietary source of both the soluble and insoluble oxalates.

Holloway *et al.,* (1989) reported that some species and some cultivars may contain the oxalate as 400 to 600 mg/100 gram of fresh weight (FW), while others range from 700 to 900 mg/100 g (FW). The occurrence of fine needle-like crystals or raphides, made up of calcium oxalate, in tropical root crops and particularly in aroids such as taro (*Colocasia*), taro (*Xanthosoma*), giant taro, giant swamp taro and elephant foot yam have been considered either the cause or the contributing cause to the acridity of the tubers of these root crops. Budavari *et al.,* (1989) reported that the typical diets of oxalate content foodstuffs between 50 to 100 mg/2500 K/Cal/day is generally recognized as safe (GRAs). In their further report the lethal dose of oxalic acid in rats are 375mg/kg.

A diet high in soluble oxalates is widely known to be associated with an increased risk of developing kidney stones, the predominant type being composed mainly of crystals of calcium

oxalate (Simpson *et al.,* 2009). Insoluble oxalate is bound to another molecule that makes it much harder to absorb; normally calcium but also sometimes magnesium, potassium and iron (Anonymous, 2018). In the same study too much of soluble oxalate in the body prevents the absorption of calcium present in the food as the oxalate bonds the calcium to form insoluble calcium complex. They further reported that 80% of all kidney stones were composed of calcium oxalate, alone or surrounding a calcium phosphate core.

2.4.1. Occurrence of oxalate in food

According to Lewu *et al.,* (2010) fresh weight of the total oxalates content in raw cocoyam was 673.98 mg/100g and in fresh potato 261.60 mg/100g. Silver beet, spinach, rhubarb, nuts, multi-grain flours, chocolate, black tea, irritant root crops and parsley contain high level of total and soluble oxalate (Zarembski and Hodigkinson, 1962; Fasett, 1973; Brinkely *et al.,* 1981; Honow and Hesse, 2002; Chai and Leibman, 2005b; Siener *et al.,* 2006).

Due to the high level of soluble oxalates these food should be taken in to consideration for avoiding kidney stone formation. Study of Zarembski and Hodigkinson (1962), reported that oxalic acid content in various English foods were calculated to range from 70 to 150mg/day and similar study of Archer *et al.,* (1957), reported that daily oxalate intake range from 1190 to 1370 mg/day.

The difference in ranges of oxalate content is probably due to a diversity of preparation methods and deference in analytical methods. The oxalate levels found in foods are unlikely to cause oxalate poisoning during normal consumption of food as a lethal intake of oxalate is thought to be 2-30g oxalic acid (Libret and Franceschi, 1987). However, poisoning has occurred when foods, which contain very high amount of oxalate and other toxins, have been consumed (Hodgkinson, 1977).

2.4.2. Processing effect on oxalate

There are several ways of reducing the oxalic acid from foods. Soaking, steaming and cooking are effective ways of decreasing oxalate content due to leaching of the biological significant soluble oxalate in to the cooking water. Most reduction of oxalate content occur when cooking water is discarded (Savage *et al.,* 2000; Chai and Leibman, 2005a). However, the content of oxalate increases during baking due to moisture loss from the food (Albihn and Savage, 2000; Chai and Leibman, 2005a). High oxalate foods should always be cooked to reduce the oxalate

content; soaking a food prior to cooking will also reduce the oxalate contents by leaching (Noonan and Savage, 1999).

According to Lewu *et al.,* (2010) cooking significantly reduce the levels of oxalate content in cocoyam and potato tubers. Thus the mean values for calcium oxalate reduced by about 50% in both cocoyam and potato after boiling in water for 20 min.

Osisiogu *et al*. (1974) also reported that boiling cocoyam for 15 min brought about considerable reduction in the irritant effect. In another study, boiling for 60 min completely removed the irritant effect (Iwuoha and Kalu 1995), indicating that irritation and itching caused by the acridity factor may not be observed when cocoyam is thoroughly cooked (Agwunobi *et al*. 2000).

The oxalate content of the uncooked cocoyam is comparable to the reported values for sweet potato and taro (Bradbury & Holloway 1988; Iwuoha and Kalu 1995). It is also documented that oxalate content varies with species and cultivars (Osisiogu *et al*. 1974).

Food root crops regularly eaten have many beneficial nutrients but there are traces of anti-nutritional components such as cyan glycosides, oxalates, phenolic, protease inhibitors, heavy metals etc. These anti-nutritional factors when consumed in foods may have adverse effect on health through inhibition of protein digestion, growth, and Fe and Zn absorption (Omorui and Dilworth, 2007). The toxin however, is destroyed by processing techniques such as cooking, soaking and drying (FAO, 1999).

The processing of the tubers by either boiling or steaming before consumption leads to the reduction of the oxalate level (Sangketkit *et al.,* 2001).

Boiling is effective method in reducing water soluble ant nutrients as reported by Agbor *et al., (*1995). For example boiling of root crops such as taro and cassava could lead to significant reduction of oxalates and cyanide respectively. The toxin is however destroyed by processing techniques such as cooking, soaking, ensiling and drying (FAO, 1999).

Soaking and cooking food leads to losses of soluble oxalates into the cooking water resulting in less oxalates being absorbed (Chai and Leibman, 2005). High oxalate foods should always be cooked to reduce the oxalate content; soaking a food prior to cooking will also reduce the oxalate contents by leaching (Noonan and Savage, 1999).

2.4.2.1. Low pH soaking effect on oxalate

Hanson *et al.,* (1989) reported that the oxalate bioavailability depends on the pH, and the chemical composition and minerals present in the food. High level of calcium, magnesium and iron decrease the bioavailability of oxalate due to the formation of insoluble oxalate salts. Soluble oxalates are biologically significant due to their ability to be absorbed, while insoluble oxalates are not absorbed, therefore considered to be biologically significant (Albihn and Savage, 2000).

The free oxalate ion ($C_2O_4^{2-}$) is available to bind with calcium preferentially and is present in the highest proportions at high pH. The binding capacity is reduced at low pH as most of the oxalate species are semi-hydro-oxalic acid ($HC_2O_4^-$) or oxalic acid ($H_2C_2O_4$) (Simpson, *et al.,* 2009).

According to Savage and Martenson (2010) the stomach pH ranges from 1.5 to 2.0 while pH in the intestine has a mean value of 8.1. Re-formation of insoluble oxalate may take place when solubilized oxalate passes from the acidic stomach to the alkaline intestine. The pH might lead to decrease absorption of oxalate due to the re-formation of insoluble calcium oxalate crystals.

When solubilized oxalate pass through the acidic gastric tract to the alkaline intestine, some re-form insoluble oxalates and so will not be absorbed. The binding capacity increases at pH above 4.0 and slows as the pH rises (Siener *et al.,* 2001). In the same sense low pH value prepared food grades like (lemon juice, ginger juice and ethanol) for soaking can reduce the binding capacity of calcium.

Hatch *et al*., (1994) demonstrated that oxalate absorption and secretion could occur in the distal colon. It has been suggested that calcium and phosphate combine with each other in the alkaline conditions leaving free oxalates to be absorbed passively (Jaeger and Robertson, 2004).

Mineral to oxalate binding is pH dependent and binding prevents many minerals (e.g. Ca) from being absorbed in the digestive tract. The free oxalate ion ($C_2O_4^{2-}$) is potentially available to bind to calcium, while the binding capacity is reduced if the semi-dehydro-oxalic acid ($HC_2O_4^-$) or oxalic acid ($H_2C_2O_4$) species are present. The effect of pH on the relative abundance of each oxalate species was discussed by Simpson *et al.,* (2009). They stated that semi-dehydro-oxalic acid is more abundant between pH 2.5 and 4.5 and the oxalate anion is more abundant between pH 4.5and 6.5.

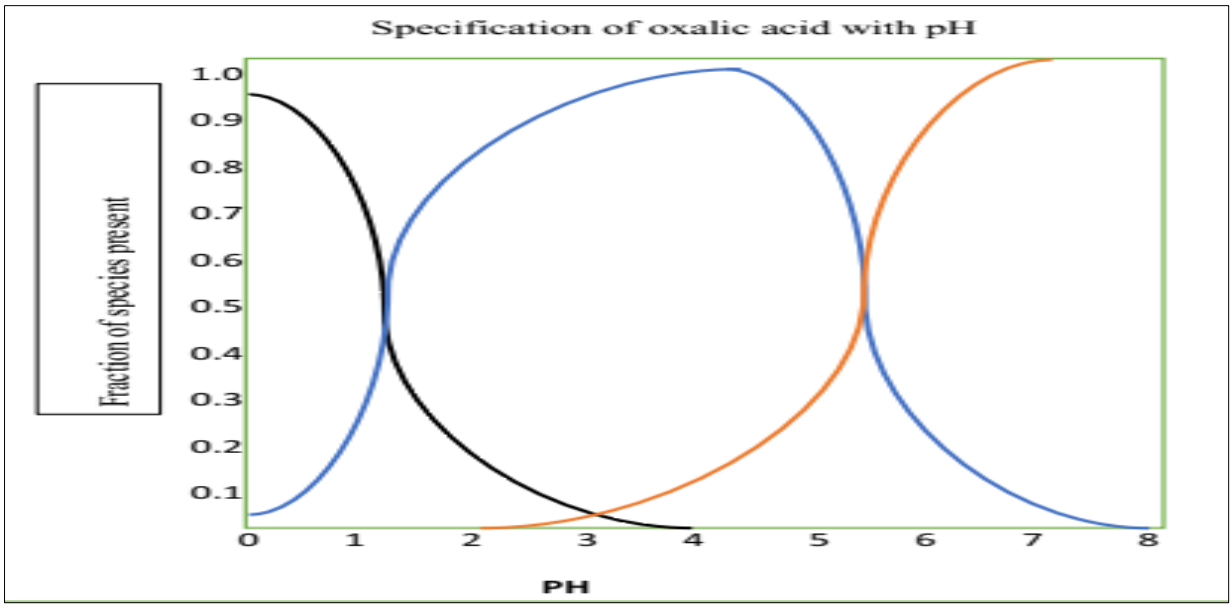


Figure 2. The pH specification of three fractions of oxalate species

The pH specification diagram for the three fractions of oxalate species present; free oxalate ion ($C_2O_4^{2-}$) ▬, semi-dehydro oxalic acid ($HC_2O_4^-$) ▬ and oxalic acid ($H_2C_2O_4$) ▬ (Simpson *et al.*, 2009).

2.4.2.2. Temperature effect on oxalate

Boiling as food processing operation could be effective in alleviating the oxalates. According to the finding of Osisiogu *et al., (*1974) the reduction of irritant effect and low oxalate content level of cocoyam after boiling for 15 min and complete disappearance after one-hour boiling. These findings have further been confirmed by the reports of Wanasundera and Ravindran (1992) who observed 40 to 50% loss of total oxalates in yam tubers (*Dioscorealata* and *D. esculenta*) upon boiling.

Some oxalate containing food stuff like vegetables are usually consumed both as raw and/or after cooking, whereas the Amochi roots are cooked or processed before consumption. A number of studies have been conducted in various parts of the world to determine the oxalate contents of local foods and the effects of cooking and processing on it. Cooking foods with water, in particular boiling has been reported to produce variable effects on their oxalate contents, primarily due to loss of soluble oxalate in cooking water (Yadav and Sehgal, 2018).

The effect of boiling on oxalate and acridity of elephant foot yam (*Amorphophallus paeoniifolius)* was studied by Kumoro *et al.*, (2014). It was concluded that boiling caused as an appreciable reduction in oxalate content (both soluble and total) as well as sensorial acridity score. Boiling elephant foot yam for ten minutes was found to be sufficient in reducing the oxalates way below the reported safer level of 71 mg/100g.

3. MATERIALS AND METHODS

3.1. Description of the Area

This study was conducted in two areas; one is Dita Woreda which is sub-administrative zone of Gamo that is used for Amochi tuber collection and, another area is Arbaminch University which is one of Ethiopian governmental University, used for Amochi tuber processing and analysis. The Amochi tuber for the present studies was procured from the farmers of Dita located in Gamo, Southern Ethiopia.

Dita is about 58 km from Arba Minch town and 603 km from the capital city of Ethiopia, Addis Ababa. In Dita the tuber was collected from two locations namely Giyassa and Dalbansa, which are located at an altitude ranging from 1700 – 2400 meter above sea level 6º11.5' N latitude and 37º29.5' E longitude (Figure 3).

The topography of this study area is hilly, with a 13% slope and a clay loam soil texture with 77 % aluminum saturation (Haile and Boke, 2011). The soil has a weak medium sub angular blocky structure with consistence that is friable when moist and slightly plastic under wet condition and a pH of 4.8.

The annual rain fall distribution varies from 900 mm to 1200 mm in the study region, with a bi-modal rainfall pattern, allowing two cropping seasons in a year (i.e., the long and the short rains). The long rainy season extends from July to November whereas; the short rainy season is between March and May with minimum rainfall in December.

Based on meteorological measurements the minimum temperature of the area is 19℃ and maximum temperature of 25℃. Despite their proximity the sites differ in some culture and agro ecology. These sites were considered as the research site because of pioneering use of Amochi as a food crop by the local population of the area.

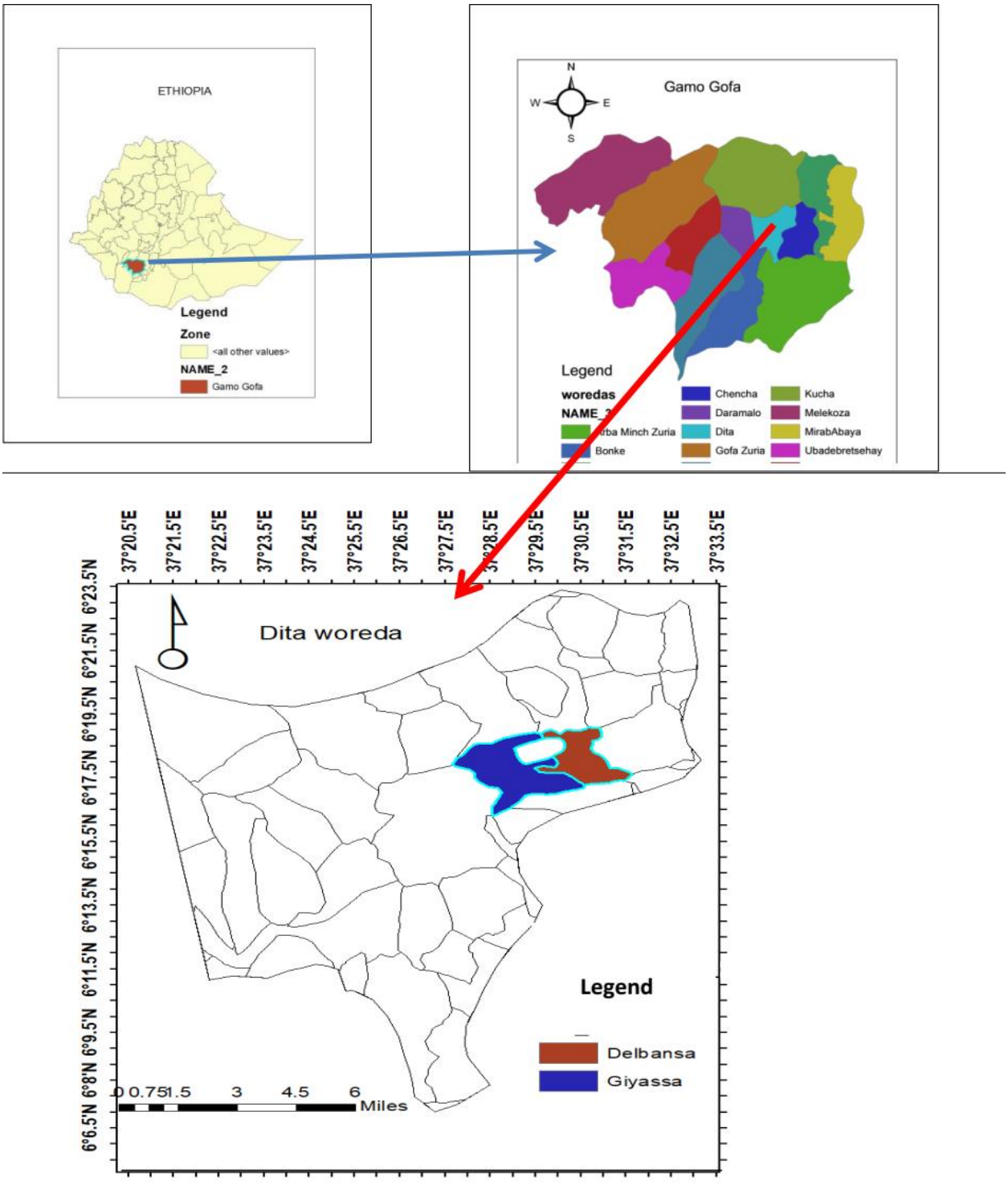


Figure 3. Map of the study area**.**

3.2. Sample Collection

Amochi tubers were collected from Dita Woreda Gamo sub-administrative zone. This area is known in Ethiopia for production and consumption of Amochi for food purpose in case of off season. With an objective to give a proper coverage to the area two similar sites, were selected in the area for collection of Amochi tubers. Amochi samples comprised of different sized tubers (large, medium and small) and free from mechanical and pest damage.

Samples were directly purchased from randomly selected farmers, they were packed in polyethylene plastic bags after ensuring uniformity, labelled and transported to Horticulture and Chemistry Department, Arbaminch University for processing and Ethiopia Public health Research Institute, Addis Ababa for analysis.

Lemon fruit having the uniform size, shape, colour and free from any mechanical and pest damage was purchased from sickle local market, Arba Minch town. Lemon juice extraction was completed by manually after cutting the fruit in two parts and the juice extract was collected in plastic jock. Ginger root which have the same freshness, mechanical and pest damage free was purchased from sickle local market, Arba Minch town. Extraction was completed by using juice maker after finely slicing with steeliness steel knife and the juice extract was collected in plastic jock. Alcohol/ethanol was purchased from local alcohol and processing house of Arba Minch town.

3.3. Experimental Design and Treatments

The experiment comprised of soaking the sliced tubers in three different pH value (*, ** & ***) and subsequently boiling and drying. Thus is total there was twelve different treatments with three replications. The experimental design was arranged factorial in a completely randomized design (CRD).

Table 1 Experimental design layout.

Treatments	Replication I				Replication II				Replication III			
	No soaked (NS)	**Soak in ginger (SG)**	**Soak in lemon (SL)**	**Soak in ethanol (SEt)**	**No soaked (NS)**	**Soak in ginger (SG)**	**Soak in lemon (SL)**	**Soak in ethanol (SEt)**	**No soaked (NS)**	**Soak in ginger (SG)**	**Soak in lemon (SL)**	**Soak in ethanol (SEt)**
Not heated (NH)	NH*NS	NH*SG	NH*SL	NH*SEt	NH*NS	NH*SG	NH*SL	NH* SEt	NH*NS	NH*SG	NH*SL	NH*SEt
Boiling (B)	B*NS	B*SG	B*SL	B* SEt	B*NS	B*SG	B*SL	B* SEt	B*NS	B*SG	B*SL	B*SEt
Drying (D)	D*NS	D*SG	D*SL	D* SEt	D*NS	D*SG	D*SL	D* SEt	D*NS	D*SG	D*SL	D*SEt

Where: NH: not heated, B: boiling, D: drying, NS: not soaked, SG: soaked with ginger juice, SL: soaked with lemon juice and SEt: soaked with ethanol. The pH value, boiling temperature time combination and drying temperature time combination of each treatment were presented in Appendices 15 and 16.

Key of pH value:-

* = 2.01 ±0.1 (lemon juice) strong acid; ** = 3.59 ±0.5 (ginger juice) medium acid and *** = 5.12 ±0.4 (ethanol) weak acid.

3.4. Amochi Sample Preparation

3.4.1. Amochi sample soaking

Amochi samples were gently washed and peeled carefully using stainless steel knives. The peeled Amochi samples were washed, rinsed with deionized water and then sliced to a uniform size of three centimeter, and distributed in different four lots. Each of the lots was sub-divided in to three sub-lots.

Three sub-lots were separately soaked in 1:2 ratio of amochi slice in kilogram to solutions in liter for two days at room temperature in the solutions of ethanol, ginger juice and lemon juice having its pH value of 5.12, 3.59 and 2.01 respectively. Three sub-lots were not soaked in any solution. Each solutions was drained off after soaking process completed. For each of treatment one out of the three lots was subsequently boiled in water, one was dried in oven and one was neither boiled nor dried.

3.4.2. Amochi sample boiling

After soaking the Amochi slices in three different solvents, one sub-lot from each solvent was used for boiling at 100℃ in potable water for 20 minutes. The boiling water was discarded after boiling process completed. The boiling process was performed using an electrical heating of (model-GMP-MSI-83, China).

3.4.3. Amochi sample drying

The second sub-lot of each treatment was dried in oven dry (model GX- 3020, GAOXIO, Co, Ltd, China) at 70℃ for 15 hours. The third sub-lot was neither dried nor boiled which is referring to the farmers practice (control).

3.5. Anti-Nutrient Determination

3.5.1. Total oxalate content determination

The oxalate contents of Amochi samples were determined using the method developed by Iwuoha and Kalu (1995). For each treatment Amochi samples of four-gram sample were suspended in 190 milliliters of distilled water Contained in 250 ml conical (Erlenmeyer) flask; 10 milliliter of 6 mole hydrochloric acid was added and the suspension was then digested at 100°C for 1 hour. This was followed by cooling. The solution were made up to 250 ml mark using distilled water and filtered in to another flask.

Duplicated portions of 125 ml of the filtrate were measured into a beaker and 3-4 drops of methyl red indicator were added, followed by the addition of concentrated ammonium hydroxide solution with drop wise until the test solution changed from its salmon pink color to a faint yellow color. The pH at this stage was recorded as (4.5-5.1).

Each portion was then heated to 90°C, cooled and filtered to remove precipitate containing ferrous ion. The filtrate was again heated to 90°C and 10 ml of 5 percent calcium chloride solution was added and stirred constantly. After heating it was cooled and left overnight at 5°C.

The cooled solution was then centrifuged at a speed of 2500 rpm for 5 minutes. The supernatant was decanted, and the precipitate completely dissolved in 10 ml of 20 percent (v/v) sulphuric acid solution. The total filtrate resulted from digestion of four gram of Amochi flour were made up to 300 ml. Aliquots of 125 ml of the filtrate were heated till boiling, and then titrated against 0.079 M standardized potassium permanganate solutions to a faint pink color which persisted for 30 seconds. The total oxalate content calculated as:

$$\frac{T \times (Vme) \times (Df) \times 10^5}{Me \times Mf.}$$

Where T is the titer of KMnO4 (mg/100g), (ml), Vme is the volume-mass equivalent in which 1 cm^3 of 0.079 M $KMnO_4$ is equivalent to 0.00225g anhydrous oxalic acid), Df is the dilution factor, Me is the molar equivalent of KMnO4 in oxalate ($KMnO_4$ redox reaction) and Mf is the mass of flour used.

3.5.2. Soluble oxalate determination

Soluble oxalate contents of the Amochi samples were determined following the method outlined by Savage *et al.,* (2000*).* For each of Amochi samples 0.5 gram of finely grounded Amochi flour was used to measure the soluble oxalate content.

40 ml of distilled water was added for the extraction of soluble oxalates. Shaking of the flask placed in an 80℃ water bath for 20 minutes was continued. Subsequently solutions were allowed to cool to 20℃ and then made up to 100 ml with distilled water.

The extract in the volumetric flask was filtered through a cellulose acetate syringe filter with a pore size of 0.45 µm into 1mL glass high performance liquid chromatography vials. The Amochi

samples were analyzed with a high-performance liquid chromatography (HPLC) system, used a 300 mm x 7.8 mm.

The analysis was performed by injected 20µL of Amochi sample onto the column using an aqueous solution of 25M. Sulphuric acid was used as the mobile phase, then pumped at 0.6 ml/min, and peaks were detected at 210 nm.

The HPLC equipment consisted of a Shimadzu LC -10AD pump, CTO -10A column oven, SPD-10Avp UV-Vis detector (Shimadzu, Kyoto, Japan) and A Waters 717 plus auto-sampler (Waters, Milford, MA, USA). Data acquisition and processing was undertaken using the peak simple chromatography data system (Model 203) and peak simple software version 4.37 (SRI Instruments, Torrance, CA, USA).

The soluble oxalate peak was identified by comparing the retention time with a standard solution and by spiking an already filtered sample containing a known amount of soluble oxalate standard. The insoluble oxalate content was calculated by the difference between the total oxalate and soluble oxalate contents.

3.6. Proximate Composition Analysis

3.6.1. Moisture determination

The method described by AOAC (2005), was used to determine moisture content of Amochi samples. The method was based up on the removal of water from the sample and its measurement by loss of weight. Clean crucible was weighted and dried in the oven (W_1), one gram of each sample was weighted in to crucible (W_2) and dried at oven 105℃ for 24 hours. The crucible were transferred from oven to desiccator, cooled and re-weighted (W_3). The percentage of moisture content was calculated as: $\frac{w2 - w3}{w2 - w1}$ x 100.

3.6.2. Ash determination

The AOAC (2005) method was used to measure the ash content of Amochi sample. The porcelain crucible were dried in an oven at 100℃ for 10 minutes, cooled in a desiccator and Weighed (W_1).

Two gram of the sample placed into the previously weighed porcelain crucible and reweighed (W_2) and then placed in the furnace for four hours at 600℃ to ensure proper ash. The crucible

containing the ash was removed cooled in the desiccator and weighed (W_3). The ash content of Amochi was calculated as: $\frac{w_3 - w_1}{w_2 - w_1}$ x 100.

3.6.3. Crude fiber determination

The method described by AOAC (2005), was used. As original sample (w_0)one gram of the finely ground sample was weighed out into a round bottom flask, 100 ml of 1.25 percent sulphuric acid solution was added and the mixture boiled under a reflux for 30 minutes. The hot solution was quickly filtered under suction.

The insoluble matter washed several times with hot water until it was acid free. It was quantitatively transferred into the flask and 100 ml of hot 1.25 percent sodium hydroxide solution added and the mixture boiled again under reflux for 30 min and quickly filtered under suction. The soluble residue washed with boiling water until it was base free.

It was dried to constant weight in the oven at 105℃, cooled in a desiccator for 30 minutes and weighed (w_1). The weighed sample (w_1) was incinerated in a muffle furnace at 300 ℃ for about 30 minutes, cooled in the desiccator for 30 minutes and reweighed (W_2). The loss in weight of sample on incineration was calculated as: $\frac{w1 - w2}{w0}$ x 100.

3.6.4. Crude fat determination

The Amochi fat content was determined as with method of AOAC-2003.05 (2005). Known amount of sample (w_0) in a round bottom flask, containing few anti-bumping granules weighed (w_1) and 150 ml of petroleum ether was transferred into the flask fitted with Soxhlet extraction apparatus. The round bottom flask and a condenser was connected to the Soxhlet extractor and cold-water circulation was put on.

The heating mantles are switched on and the heating rate adjusted until the solvent was refluxing at a steady rate. Extraction was carried out for 6 hours. The round bottom flask and extracted oil are cooled and then weighed (w_2) and the fat content of Amochi sample was calculated as:

$\frac{w_2 - w_1}{w_0}$ X 100.

3.6.5. Crude protein determination

Crude protein was determined by method described by AOAC-960.52 (2005). One gram of each sample was weighed into separated digestion flask and 10 gram of a catalyst sodium sulphate, copper sulphate and 25 ml of concentrated Sulphuric acid was added. The sample heated on a micro digestion bench which is thermostatically controlled to remove organic carbon for 2 hours. After heating, the content of the flask was left to cool and transferred to a round bottom flask with distilled water.

A little piece of anti-bumping granules was added to prevent pumping and 80 ml of 40% sodium hydroxide solution carefully added, mixed and then subjected to distillation until all the ammonia passed over into the standard sulfuric acid solution. It was titrated with standard 0.55 mole of sodium hydroxide solution to an end point. The conversion factor 6.25 was used to get the percentage protein contents.

3.6.6. Carbohydrate determination

The total carbohydrate content was determined by followed (Muller and Tobin, 1980) method. The percentage sum of the moisture, ash, crude protein and crude fiber was subtracted from 100. Total carbohydrate content of Amochi sample was calculated as: 100 minus percentage of (moisture + Ash + fat + protein + crude fiber).

3.7. Minerals Determination

Standard AOAC (1990) method was used to digest 2.0g flour samples. One hundred milliliter (100ml) standard solutions were prepared from the digest and used for the mineral analysis. Minerals (calcium, magnesium, zinc and iron) were determined using standard analytical methods.

Part of the standard solution of the digest was used to determine Ca, Mg, Zn and Fe using Perkin Elmer Atomic Absorption Spectrophotometer (Model AAS-3, Carl Zeiss, Germany), with air acetylene flame at 422, 286, 720 and 722 nm respectively.

3.8. Data Analysis

The collected data was subjected to analysis of variance (ANOVA) by using SAS software version 9.0. Means separation was done using Duncan's multiple range tests at 5% level of significance.

4. RESULTS AND DISCUSSION

4.1. Proximate Composition on Amochi

Proximate composition of the raw and processed Amochi are presented in Table 2. On fresh weight basis 65.45 % carbohydrate, 0.54 % crude protein, 0.59 % crude fiber, 0.11 % crude fat, 1.34 % ash and 32.39 % moisture were recorded in fresh Amochi whereas in processed Amochi the percentage values of carbohydrate ranged from 67.13 to 85.05 %, crude protein 0.42 to 0.82 %, crude fiber 0.41 to 0.82 %, crude fat 0.11 to 0.24 %, ash 1.33 to 2.74 % and moisture 11.57 to 30.48 %.

4.1.1. Moisture content

Moisture content of the raw and processed Amochi is presented in Table 2. The moisture content of 32.39 % on fresh weight was recorded in fresh Amochi, whereas it ranged from 11.57 to 30.48 % in the processed one. A moisture percentage of 11.57 %, 12.58 %, 12.62 % and 14.71 % was observed in dried Amochi treated with ginger juice, oven dried Amochi, dried Amochi treated with ethanol and dried Amochi treated with lemon juice respectively. This could be due to removal of water during drying. Heating and soaking interaction had significantly ($P < 0.05$) affected the Amochi moisture content (Appendix 1).

These results are in close conformity to the report of Shittu *et al.,* (2007) who reported moisture content of 11 % to 16.5 % in all dried root and tuber crops. High moisture content of dried root crops reduces shelf life and permits microbial growth constituting health hazards for animal feeding on such products (Padonou *et al.,* 2010).

Table 2 Interaction effect of heating and soaking on proximate composition of Amochi.

Treatments	Moisture (%)	Crude fiber (%)	Ash (%)	Crude protein (%)	Crude fat (%)	Carbohydrate (%)
Control	32.39 ±0.98^{a}	0.59 ±0.021^{d}	1.34 ±0.005 ^{f}	0.54 ± 0.017^{c}	0.11 ±0.1^{g}	65.45 ±1.3^{h}
Fresh Amochi treated with ginger	29.23 ±1.11^{bc}	0.46 ±0.37^{fhg}	1.41 ±0.005^{f}	0.48 ±0.006^{d}	0.19 ±0.001^{b}	68.21 ±1.09^{fg}
Fresh Amochi treated with lemon	27.92 ±0.62^{c}	0.43 ±0.26^{hg}	1.38 ±0.005^{f}	0.61 ±0.06^{b}	0.16 ±0.001^{c}	68.85 ±0.54 ^{f}
Fresh Amochi treated with ethanol	30.48 ±0.53^{b}	0.47 ±0.037^{feg}	1.33 ±0.01^{f}	0.42 ±0.006 ^{f}	0.15 ±0.05^{cd}	67.13 ±0.56^{g}
Boiled Amochi with not soaked	18.36 ± 0.8^{ed}	0.41 ±0.0046^{h}	2.74 ±0.01^{a}	0.52 ±0.01^{c}	0.20 ±0.005^{b}	77.75 ±0.81^{ed}
Boiled Amochi treated with ginger	17.68 ± 0.76 ^{e}	0.45 ±0.07^{ghf}	2.22 ±0.01^{c}	0.42 ±0.057 ^{f}	0.20 ±0.005^{b}	79.00 ±0.74^{d}
Boiled Amochi treated with lemon	18.33 ±1.12^{ed}	0.52 ±0.01^{e}	1.98 ±0.005^{d}	0.47 ±0.005^{de}	0.24 ±0.01^{a}	78.49 ±1.06^{d}
Boiled Amochi treated with ethanol	19.60 ± 0.68^{d}	0.48±0.006^{fe}	2.51 ±0.3^{b}	0.53 ±0.007^{c}	0.15 ±0.01^{cd}	76.68 ±0.84^{e}
Dried Amochi with not soaked	12.85 ±0.69^{g}	0.73 ±0.01^{c}	1.97 ±0.005^{d}	0.82 ±0.0057^{a}	0.13 ±0.00^{ef}	82.81 ±0.45^{cb}
Dried Amochi treated with ginger	11.57 ±0.52^{g}	0.75 ±0.009^{cb}	1.86 ±0.005^{de}	0.62 ±0.0066^{b}	0.12 ±0.01^{gf}	85.05 ±0.51^{a}
Dried Amochi treated with lemon	14.71 ±0.59 ^{f}	0.78 ±0.005^{ba}	1.78 ±0.005^{e}	0.44 ±0.007^{fe}	0.11 ±0.02^{gf}	82.12 ±0.06^{c}
Dried Amochi treated with ethanol	12.62 ±0.70^{g}	0.82 ±0.01^{a}	1.88 ±0.01^{de}	0.61 ±0.005^{b}	0.14 ±0.01^{ed}	83.91 ±0.72^{ba}
CV %	3.87	5.01	5.40	3.64	6.12	1.07
LSD	1.3373	NS	0.1704	NS	NS	1.3841

Means followed by the same letter(s) within a column are not significantly different at p < 0.05%; CV: coefficient of variation, LSD: Least significant difference and NS: Not significant.

4.1.2. Carbohydrate

Carbohydrate content of the raw and processed Amochi is presented in Table 2. Heating and soaking interaction had significantly ($P < 0.05$) affected the Amochi carbohydrate content (Appendix 2).

The carbohydrate content of 65.45 % on fresh weight was recorded in fresh Amochi, whereas it ranged from 67.13 to 85.05 % in processed Amochi. A highest carbohydrate percentage of 85.05 % and 83.91 % were observed in dried Amochi treated with ginger juice and dried Amochi treated with ethanol respectively, whereas the lowest percentage of 65.45% was observed in unprocessed Amochi. That could be due to the removal of water during drying.

Though the composition of fresh Amochi in respect of carbohydrate has been reported 65.94 % to *Arisaema concinnum* (Dutta, 1909), but no literature is available on the carbohydrate content in processed Amochi. The other root and tuber crops growing in the study area were studied by Bukola (2017), who reported carbohydrate content of 86.79 %; 79.67 % and 79.36 % in Potato; Sweet potato and yam respectively, in fresh crops.

Comparing the Amochi carbohydrate content with the finding of earlier works Bukola (2017) for potato, sweet potato and yam it can concluded that the Amochi serve a source for carbohydrate supply like other root and tuber crops commonly being consumed.

In the present studies dried Amochi treated with ginger juice had the highest carbohydrate content of 85.05%, which is comparable to the carbohydrate content in dried root and tuber crops reported by Bukola (2017), who reported carbohydrate percentage of 86.79 % in Potato, 79.67 % in Sweet Potato, 79.36 % in Yam, 76.42 % in Cassava and 75.93 % in Dalo.

4.1.1. Protein

Crude protein content of the raw and processed Amochi are presented in Table 2. Heating and soaking interaction significantly ($P < 0.05$) affected the Amochi crude protein content (Appendix 3). The crude protein content of 0.54 % on fresh weight bases was recorded in fresh Amochi, whereas it ranged from 0.42 to 0.82 % in processed Amochi. A crude protein content of 0.82 %, 0.62 %, and 0.61 % was observed in oven dried Amochi not soaked, dried Amochi treated with ginger juice, and dried Amochi treated with ethanol respectively.

Oven dried Amochi not soaked had highest protein content (0.82 %), whereas dried Amochi treated with ethanol had lowest protein content (0.42 %). That could be due to that alcohol-soluble protein fractions solubilized and precipitated in ethanol solution and drained off with ethanol. These variations could be probably due to variety, location maturity and processing technique difference (Seerley 1972).

Though there is no literature available on the protein content of processed Amochi, but the reports of earlier research on the other root and tuber crops indicate that crude protein content of African yam is 4.5 percent (Odebunmi *et al.,* 2007). Osagie and Eka (1998), reported African yam having highest crude protein 7.66 percent and lowest value in cassava 3.72 percent.

4.1.3. Ash

Ash content of the raw and processed Amochi is presented in Table 2. The heating and soaking interaction significantly ($P < 0.05$) affected the Amochi ash content (Appendix 4). The ash content of 1.34 % on fresh weight was recorded in fresh Amochi, whereas it ranged from 1.33 % to 2.74 % in processed Amochi. The highest ash content of 2.74 % and 2.51 % was observed in boiled Amochi and boiled Amochi treated ethanol respectively, whereas the lowest ash percentage of 1.33 was observed in fresh Amochi treated with ethanol. That may be due to leaching of soluble minerals in low pH solution and damaging of cell wall of the Amochi resulting in leaching of not only the dissolved ones, but also those dispersed in the solution.

Dutta, (1909) reported that unprocessed Amochi ash content of 7.60% on *Arisaema concinnum*, thus this studies contrary the ash percentage. This could be due to the species difference and that leaching of soluble minerals drained off with soaked solvents and boiling water. Processing of Amochi like (washing, slicing, blanching or cooking) causes statistically significant decrease in ash (Kmiecik *et al.,* 2007). The percentage of ash content in sample gives an idea about the inorganic content of the samples from where the mineral content could be obtained. Samples with high percentages of ash contents are expected to have high concentrations of various mineral elements, which are expected to speed up metabolic processes and improve growth and development (Bello *et al*., 2008).

4.1.4. Crude fiber

Perusal of Table 2 reveals that crude fiber content of 0.59 % on fresh weight was recorded in fresh Amochi, whereas in case of Amochi treated with ginger juice it was 0.46 %; Amochi treated with lemon juice 0.43 %; Amochi treated with ethanol 0.47 %; boiled Amochi not soaked 0.41 %; boiled Amochi treated with ginger juice 0.45 %; boiled Amochi treated with lemon juice 0.52 %; boiled Amochi treated with ethanol 0.48 %; dried Amochi not soaked 0.73 %; dried Amochi treated with ginger juice 0.75 %; dried Amochi treated with lemon juice 0.78 % and dried Amochi treated with ethanol 0.82 %.

Thus, the highest crude fiber content of 0.82% was observed in dried Amochi treated with ethanol whereas the lowest crude fiber content of 0.41% was observed in boiled Amochi not soaked. This could be mainly due to the loss of soluble fiber during boiling & drained off with boiling water. Heating and soaking interaction had a significant ($P < 0.05$) effect on the crude fiber content of Amochi (Appendix 5).

This study is in line with the work of Gil and Buitrago (2002), who reported that crude fiber does not exceed (1.5%) in fresh root crops and (4.0%) in processed root crops depending on the variety and the age of the root.

4.1.5. Crude fat

Crude fat content of the raw and processed Amochi is presented in Table 2. A crude fat content of 0.11 % on fresh weight bases was recorded in fresh Amochi, whereas it ranged from 0.11 % to 0.24 % in processed Amochi. The highest fat content 0.24 % was observed in boiled Amochi treated with lemon juice followed by boiled Amochi treated with ginger juice 0.20%. These variation of fat could be probably due to boiling temperature increase extractability of the more polar fat or fats that are bound to other macro constituents in the Amochi tissue. The interaction effect of heating and soaking significantly ($P < 0.05$) affected the Amochi fat content (Appendix 6). These findings are close to the results of Charles *et al.*, (2005) who reported that the root and tuber meal contains fat content ranges from (0.1 % to 0.3 %) on a dry weight basis.

4.2. Mineral Composition on Amochi

Minerals composition content of the raw and processed Amochi are presented in Table 3. On fresh weight basis 17.83 mg/100g calcium, 22.32 mg/100g magnesium, 8.71 mg/100g zinc and 8.95 mg/100g iron were recorded in fresh Amochi, whereas in processed Amochi the mineral content ranged from 6.35 mg/100g to 16.23 mg/100g for calcium, 10.74 mg/100g to 21.29 mg/100g for magnesium, 3.44 mg/100g to 7.67 mg/100g for zinc and 3.70 mg/100g to 7.56 mg/100g for iron. All the selected mineral composition contents significantly decreased after processing of Amochi. The percentage reduction ranged from 8.44 % to 64.21 % for calcium, 6.29 % to 52.81 % for magnesium, 11.49 % to 60.5 % for zinc and 15.53 % to 58.65 % for iron.

Table 3 Interaction effect of heating and soaking on calcium, magnesium, zinc and iron content of Amochi (mg/100g).

Treatments	Ca (mg/100g)	Mg (mg/100g)	Zn (mg/ 100g)	Fe (mg/100g)
Control	17.83 ±0.83^{a}	22.72 ±0.63^{a}	8.71 ±0.22^{a}	8.95 ±0.45^{a}
Fresh Amochi treated with ginger	13.29 ±0.43^{e}	18.69 ±0.46^{dc}	6.32 ±0.26^{e}	6.58 ±0.4^{ed}
Fresh Amochi treated with lemon	11.54 ±0.49^{f}	15.55 ±1^{e}	6.71 ±0.19^{d}	5.77 ±0.17^{fg}
Fresh Amochi treated with ethanol	15.60 ±0.25^{c}	20.89 ±0.76^{b}	7.42 ±0.35^{cb}	7.31 ±0.39^{bc}
Boiled Amochi not soaked	9.55 ±0.35^{h}	18.12 ±0.02^{d}	6.47 ±0.27^{ed}	6.26 ±0.24^{fe}
Boiled Amochi treated with ginger	7.39 ±0.16^{j}	16.24± 0.39^{e}	5.5 ±0.13^{f}	5.5 ±0.63^{g}
Boiled Amochi treated with lemon	6.38 ±0.21^{k}	10.74 ±0.66^{f}	3.44 ±0.26^{g}	3.70 ±0.20^{h}
Boiled Amochi treated with ethanol	8.42 ±0.13^{i}	15.71 ±0.4^{e}	6.30 ±0.12^{e}	6.8 ±0.6^{ced}
Dried Amochi not soaked	16.23 ±0.1^{b}	21.29 ±0.29^{b}	7.36 ±0.22^{cb}	7.01 ±0.12^{cbd}
Dried Amochi treated with ginger	14.26 ±0.22^{d}	19.51 ±1^{c}	7.22 ±0.21^{c}	7.17 ±0.27^{cbd}
Dried Amochi treated with lemon	10.17 ±0.15^{g}	17.93 ±1^{d}	6.43 ±0.52^{ed}	6.78 ±0.34^{ced}
Dried Amochi treated with ethanol	15.38 ±0.13^{c}	20.70 ±0.43^{b}	7.67 ±0.1^{b}	7.56 ±0.19^{b}
CV %	2.98	3.83	3.30	5.63
LSD	0.613	1.1745	0.3697	0.6283

Means followed by the same letter(s) within a column are not significantly different at $p < 0.05$ %; Ca: calcium, Mg: magnesium, Zn: zinc, Fe: iron, CV: coefficient of variation and LSD: least significant difference.

4.1.2. Calcium

The interaction of heating and soaking had significantly ($p < 0.05$) affected the calcium content of Amochi (Appendix 7). Calcium content of 17.83 mg/100g on fresh weight was recorded in unprocessed Amochi/control, whereas it ranged from 6.38 mg/100g to 16.23 mg/100g in processed Amochi (Table 3).

The highest calcium content of 17.83 mg/100g, 16.23 mg/100g, 15.60 mg/100g and 15.35 mg/100g were observed in fresh Amochi, oven dried Amochi, Amochi treated with ethanol and dried Amochi treated with ethanol respectively. The lowest calcium content of 6.38 mg/100g was observed in boiled Amochi treated with lemon juice followed by boiled Amochi treated with ginger juice 7.39 mg/100g.

The highest loss percentage of calcium 64.21 % and 58.55 % were observed in boiled Amochi treated with lemon juice and boiled Amochi treated with ginger juice respectively, whereas the lowest loss percentage of calcium 8.4 % and 11.9 % were observed in dried Amochi not soaked and ethanol treated Amochi respectively. This could be due to high leaching of the calcium with the boiling water & high soluble in low pH of lemon juice.

Esayas (2009), reported that the reduction of calcium content from 21.8 to 8.67 mg/100g) in taro after boiling. The present finding shows a similar trend. This could be due to high leaching of the calcium with the heating (boiling water) that contributes for the decrement of the calcium content. Sofia (2010), reported that the overall calcium content was lower in low pH value of yoghurt test meal and low fat yoghurt meal (4.08 and 4.25 pH value) respectively than in the stir-fried silver beet meals of pH value (5.67).

4.2.1. Magnesium

Magnesium content of the raw and processed Amochi is presented in Table 3. The heating and soaking interaction had significantly ($p < 0.05$) affected the magnesium content of Amochi (Appendix 8).

Magnesium content of 22.72 mg/100g on fresh weight was recorded in unprocessed Amochi/control, whereas it ranged from 10.74 mg/100g to 21.29 mg/100g in processed Amochi. The highest magnesium content of 22.72 mg/100g, 21.29 mg/100g, 20.89 mg/100g and 20.70 mg/100g were observed in unprocessed Amochi/control, dried Amochi not soaked,

Amochi treated with ethanol and dried Amochi treated with ethanol respectively, whereas the lowest magnesium content of 10.74 mg/100g was observed in boiled Amochi treated with lemon juice followed by Amochi treated with lemon juice 15.55 mg/100g. This might be due to the fact that magnesium in oxalate has less solubility (Poeydomenge *et al*., 2007).

The magnesium content in fresh Amochi was relatively higher than other selected minerals of Amochi samples. The least percentage loss (6.29 %) of magnesium during processing was observed in the dried Amochi, whereas the highest percentage loss (52.81 %) was observed for boiled Amochi treated with lemon juice. That could be due to the boiling point of water and low pH value of lemon and ginger (2.01 and 3.59 respectively). Processing treatments like dying and drying after soaking in lemon juice lead to much lower losses of magnesium when compared with other processing treatments like boiling after soaking with lemon juice and boiling after soaking with ginger juice. This could be due to that magnesium is less soluble in high pH and high soluble in low pH.

4.2.2. Zinc

The heating and soaking interaction had significantly ($p < 0.05$) affected the zinc content of Amochi (Appendix 9). Zinc content of the unprocessed and processed Amochi is presented in Table 3.

Zinc content of 8.71 mg/100g on fresh weight was recorded in fresh Amochi, but in case of processed Amochi it ranged from 3.44 mg/100g to 7.67 mg/100g. The highest zinc content of 8.71 mg/100g and 7.67 mg/100g were observed in unprocessed Amochi/control and dried Amochi treated with ethanol respectively. Lowest zinc content of 3.44 mg/100g was observed in boiled Amochi treated with lemon juice followed by Amochi treated with ginger juice 5.5 mg/100g. This could be due to that the zinc is leaching off with boiling water and high soluble in low pH.

Amochi can be a better option for supplementing zinc requirements than other root and tuber crops like yam. As is observed in the present finding Amochi has zinc content of ranging between 3.44 mg/100g and 8.71 mg/100g, but in the case of yam (*D. bulbifera)* highest zinc content was 8.33 mg/100g, and lowest zinc content was 0.35 mg/100g in (*D. rotundata)* as reported by Atnafua and Endashaw, (2017).

The highest percentage loss of zinc 60.5 % and 36.85 % was observed in boiled Amochi treated with lemon juice and boiled Amochi treated with ginger juice respectively, whereas the lowest percentage loss 11.94 % were observed in dried Amochi treated with ethanol.

4.2.3. Iron

The interaction of heating and soaking had significantly ($p < 0.05$) affected the iron content of Amochi (Appendix 10). The iron content of the raw and processed Amochi is presented in Table 3.

The iron content of 8.95 mg/100g was recorded in unprocessed/control treatment, whereas it ranged from 3.70 mg/100g to 7.56 mg/100g in processed Amochi. The highest iron content of 8.95 mg/100g and 7.56 mg/100g were observed in unprocessed/control and dried Amochi treated with ethanol respectively. Lowest iron content of 3.70 mg/100g was observed in boiled Amochi treated with lemon juice followed by Amochi treated with ginger juice 5.5 mg/100g. This could be due to iron present in form of insoluble complexes (Fe^{3+}) with oxalate.

The highest percentage loss of iron 58.65 % and 38.54 % was observed in boiled Amochi treated with lemon juice and boiled Amochi treated with ginger juice respectively, whereas the lowest percentage loss 15.53 % was observed in dried Amochi treated with ethanol.

The iron content shows decline after processing of Amochi. The percentage of decline ranged from 15.53 % to 58.65 % which is similar to the observation of Omoruyi *et al*., (2007) who concluded that the reduction of iron content of yam from 3.25 mg/100g to 2.52 mg/100g during boiling.

4.3. Oxalate Content on Amochi

Total oxalate, soluble oxalate and insoluble oxalate content of the raw and processed Amochi are presented in Table 4. The heating and soaking interaction significantly ($P < 0.05$) affected the total oxalate, soluble oxalate and insoluble oxalate concentration (Appendices 11, 12 and 13).

On wet basis 970.92 mg/100g total oxalate, 539.69 mg/100g soluble oxalate and 431.24 mg/100g were recorded in control/unprocessed, whereas in processed Amochi these values

ranged from 268 mg/100g to 848.68 mg/100g for total oxalate, 154.67 mg/100g to 518.73 mg/100g for soluble oxalate and 112.67 mg/100g to 329.98 mg/100g for insoluble oxalate.

The oxalate content in fresh Amochi tuber obtained varied greatly from processed Amochi. That could be due to bioavailability of the free oxalate ion in Amochi which is leaching of significant soluble oxalate in to the processing solutions. These result show that Amochi tuber has high total oxalate content than that reported by Noonan *et al.,* (1999) 278 to 574 mg/100g and 486 to 786 mg/100g of total oxalate in fresh taro and yam respectively.

From all treatments boiled Amochi treated with lemon juices had the lowest content of 268 mg/100g, 154.67 mg/100g and 112.67 mg/100g of total oxalate, soluble oxalate and insoluble oxalate respectively. This could be due to fact that boiling damages the cell wall of Amochi & soaking in lemon juice which have low pH value of (2.01) converts the free oxalate ion to semi-dehydro oxalic acid and oxalic acid, thus solubilized and dissolved oxalate is leaching and drained off with lemon juice and boiling water.

Amochi treated with ginger juice recorded the highest content of total oxalate (848.68 mg/100g) and soluble oxalate (539.69 mg/100g), but 397 mg/100g of insoluble oxalates were recorded in dried Amochi treated with ginger juice. The soluble to total oxalate ratio was found to be 55.58 percent in fresh Amochi whereas, in processed Amochi this value ranged from 48.34 to 63.61 percent. The highest total oxalate to soluble oxalate 63.61 percent was recorded in Amochi treated with ethanol, whereas the lowest percentage (48.34%) was observed in dried Amochi treated with ethanol followed by 48.51 percent in boiled Amochi treated with lemon juice.

In all treatments the value of total oxalate and soluble oxalate content is reducing except treatment not soaked in any solution and not heated in any temperature/control. The maximum reduction percentage of 72.39 percent of total oxalate and 71.34 percent soluble oxalate was observed in boiled Amochi treated with lemon juice, whereas the minimum reduction percentage of 12.59 percent total oxalate and 3.88 percent soluble oxalate were observed in treated Amochi with ginger juice. More oxalate loss is not expected if samples are dried and the boiling water is not drained off (Noonan *et al*., 1999).

The reduction percentage range of total oxalate from 12.59 to 72.39 percent was similar to the results of Esayas (2009) who reported 30 to 72 percent reduction of total oxalate in taro sample and 50-73 percent in yam samples. That could be due to the fact that boiling damages the cell wall and oxalate leached and drained off with the boiling water.

The higher percentage of oxalate reduction during soaking with lemon juice may also be due to bioavailability of the free oxalate ion in Amochi and its solubility in low pH value. Boiling may cause considerable skin rupture and facilitate the leakage of soluble oxalate into cooking water. This may be the possible reason for the observed high reduction in oxalate level upon boiling. (Bhandari *et al*., 2004).

The reduced oxalate content on cooked tubers could have positive impact on the health of consumers. The reduction of oxalate levels on soaking is expected to enhance the bioavailability of essential dietary minerals of tubers and reduce the risk of kidney stones occurring among consumers (Esayas, 2009).

Table 4 Interaction effect of heating and soaking on total oxalate, soluble oxalate and insoluble oxalate of Amochi (mg/100g).

Treatments	Total oxalate (mg/100g)	Soluble oxalate (mg/100g)	Insoluble oxalate (mg/100g)	Proportion of soluble/total oxalate in (%)
Control	970.92 ±1.45^{a}	539.69 ±1.62^{a}	431.24 ±0.83^{a}	55.58^{d}
Fresh Amochi treated with ginger	848.68 ±14.60^{b}	518.73 ±10.96^{ba}	329.98 ±3.76^{d}	61.11^{ba}
Fresh Amochi treated with lemon	611.15 ±18.11^{f}	339.61 ±17.62^{e}	271.53 ±1.63^{h}	55.53^{d}
Fresh Amochi treated with ethanol	749.55 ±11.34^{d}	476.81 ±8.26^{dc}	372.74 ±3.08^{hg}	63.61^{a}
Boiled Amochi not soaked	547.33 ±28^{g}	328.33 ±17^{e}	219 ±19^{i}	59.98^{bac}
Boiled Amochi treated with ginger	546.67 ±38.27^{g}	266.33 ±41^{f}	280.33 ±4.61^{g}	48.51^{e}
Boiled Amochi treated with lemon	268 ±22^{h}	154.67±23.75^{g}	112.67 ±2.51^{j}	56.94^{dc}
Boiled Amochi treated with ethanol	763 ±46^{dc}	445.66 ±39^{d}	317.667 ±6.65^{ef}	58.31^{bdc}
Dried Amochi not soaked	842.67 ±1.52^{b}	519 ±1^{ba}	322.67 ±2.51^{ed}	61.61^{ba}
Dried Amochi treated with ginger	764.33 ±2.88^{dc}	467.33 ±0.57^{dc}	397 ±2.64^{b}	61.13^{ba}
Dried Amochi treated with lemon	657 ±2^{e}	317.67 ±1.52^{e}	339.33 ±1.52^{c}	48.34^{e}
Dried Amochi treated with ethanol	798.33 ±3^{c}	485.67 ±1.15^{bc}	312.33 ±2.08^{f}	60.83^{ba}
CV %	3.30	5.18	1.66	3.77
LSD	38.797	35.359	8.427	3.66

Means followed by the same letter(s) within a column are not significantly different at $p < 0.05\%$; CV: Coefficient of Variation, LSD: Least significant difference.

5. CONCLUSION AND RECOMMANDATION

5.1. Conclusion

This research finding provides data on proximate composition, mineral composition and anti-nutrient (oxalate) content of Amochi grown in Dita Woreda sub-administrative zone of Gamo, Southern Ethiopia. Amochi tuber grown in the area have been consumed as an alternate food by local population for more than four decades. There was no pre-bench marked information for local population about the nutritional value and anti-nutrient content of the Amochi tuber.

Therefore, this study was initiated to investigate the chemical composition and anti-nutrient (oxalate) content in the Amochi tuber. Results revealed that heating and soaking combination significantly ($P<0.05$) influenced the proximate composition, mineral composition and oxalate contents of Amochi tuber.

Both unprocessed and processed Amochi is comparable to many root and tuber crops as a source of carbohydrates. But it is richer in most of the minerals than many other root and tuber crops. Anti-nutritional factor (oxalate) is the major hindrance for use of Amochi as an alternate food source. Oxalate binds minerals and makes them unavailable to the body. Besides making the minerals non-available, health related issues are caused by the presence of oxalate in Amochi.

The combination treatment of Amochi tuber in soaking with lemon juice and boiling has been found to be effective in reducing the oxalate in Amochi. pH value of 2.01 created by lemon juice was found to be most effective among the presents treatments for reducing the oxalate content of Amochi. The reduction of oxalate in this treatment was the highest order of 72.39 percent.

It can be concluded that heat treatment that included boiling after soaking in low pH solvent like in lemon juice pH value of 2.01 can be very helpful in reducing the level of anti-nutritional factor (oxalate) in Amochi. The lower pH value of solvent has more ability of reducing the oxalate, as is observed in the present study.

5.2. Recommendations

In view of the present finding it is recommended that: areas where Amochi is already consumed as an alternate food need to be educated about the processing techniques which reduces the content of anti-nutritional factor (oxalate) in the Amochi. Boiling and soaking in low pH solvents like lemon juice can be a better option of processing.

Practical demonstration in the area for processing need to be conducted and skill of the population especially those of housewives need to be arranged for imparting training in the processing techniques.

The quantity of Amochi to be consumed daily should not exceed the recommended limits (50 to 100mg/100g oxalate for 2500 Kcal/day). Keeping these levels as a base the consumption can be worked out taking into consideration oxalate content of 268 mg/100 g in amochi treated with lemon juice after boiling.

More detailed studies need to be taken by various researchers, organizations or universities for studying on other anti-nutritional factors (phytate and tannin) content, physico-chemical composition, blended composite of cereal grains/legumes to Amochi products and processing technologies which can lead for more advantageous use of the produce.

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APPENDICIES

Appendix 1 Mean squares of ANOVA for moisture as affected by heating, soaking and interaction

Source	DF	Mean Square	F	Pr.
Heating	2	909.073144	1443.59	<.0001
Soaking	3	5.06965185	8.05	0.0007
Heating*soaking	6	6.458885	10.26	<.0001
Error	24	-	-	-
CV%	3.87	-	-	-

Appendix 2 Mean squares of ANOVA for carbohydrate as affected by heating, soaking and interaction

Source	DF	Mean Square	F	Pr.
Heating	2	799.907724	1185.72	<.0001
Soaking	3	7.119636	10.55	0.0001
Heating*soaking	6	3.739669	5.57	0.0001
Error	24	-	-	-
CV%	1.07	-	-	-

Appendix 3 Mean squares of ANOVA for protein as affected by heating, soaking and interaction.

Source	DF	Mean Square	F	Pr.
Heating	2	0.06574444	166.68	<.0001
Soaking	3	0.02813333	71.32	<.0001
Heating*soaking	6	0.03492222	88.54	<.0001
Error	24	-	-	-
CV%	3.64	-	-	-

Appendix 4 Mean squares of ANOVA for ash as affected by heating, soaking and interaction

Source	DF	Mean Square	F	Pr.
Heating	2	2.97535833	291.07	<.0001
Soaking	3	0.14356296	14.04	0.0001
Heating*soaking	6	0.10257685	10.03	< .0001
Error	24	-	-	-
CV%	5.40	-	-	-

Appendix 5 Mean squares of ANOVA for fiber as affected by heating, soaking and interaction.

Source	DF	Mean Square	F	Pr.
Heating	2	0.35126944	415.98	<.0001
Soaking	3	0.00193704	2.29	0.1035
Heating*soaking	6	0.01176204	13.93	<.0001
Error	24	-	-	-
CV%	5.01	-	-	-

Appendix 6 Mean squares of ANOVA for fat as affected by heating, soaking and interaction

Source	DF	Mean Square	F	Pr.
Heating	2	0.01677025	171.32	<.0001
Soaking	3	0.00188595	10.77	<.0001
Heating*soaking	6	0.00336818	19.24	<.0001
Error	24	-	-	-
CV%	6.12	-	-	-

Appendix 7 Mean squares of ANOVA for calcium as affected by heating, soaking and interaction

Source	DF	Mean Square	F	Pr.
Heating	2	162.2252083	1226.17	<.0001
Soaking	3	43.9406704	332.12	<.0001
Heating*soaking	6	2.8282676	21.38	<.0001
Error	24	-	-	-
CV%	2.98	-	-	-

Appendix 8 Mean squares of ANOVA for magnesium as affected by heating, soaking and interaction

Source	DF	Mean Square	F	Pr.
Heating	2	79.1026083	162.86	<.0001
Soaking	3	57.7048250	118.80	<.0001
Heating*soaking	6	3.8586194	7.94	<.0001
Error	24	-	-	-
CV%	3.83	-	-	-

Appendix 9 Mean squares of ANOVA for zinc as affected by heating, soaking and interaction

Source	DF	Mean Square	F	Pr.
Heating	2	13.07530000	271.65	<.0001
Soaking	3	7.02280741	145.90	<.0001
Heating*soaking	6	1.48372963	30.83	<.0001
Error	24	-	-	-
CV%	3.30	-	-	-

Appendix 10 Mean squares of ANOVA for iron as affected by heating, soaking and interaction

Source	DF	Mean Square	F	Pr.
Heating	2	9.88730278	71.13	<.0001
Soaking	3	7.41115833	53.32	<.0001
Heating*soaking	6	1.93504722	13.92	<.0001
Error	24	-	-	-
CV%	5.63	-	-	-

Appendix 11 Mean squares of ANOVA for total oxalate as affected by heating, soaking and interaction

Source	DF	Mean Square	F	Pr.
Heating	2	250208.8312	472.05	<.0001
Soaking	3	144334.7224	272.31	<.0001
Heating*soaking	6	33713.2113	63.60	<.0001
Error	24	-	-	-
CV%	3.30	-	-	-

Appendix 12 Mean squares of ANOVA for soluble oxalate as affected by heating, soaking and interaction

Source	DF	Mean Square	F	Pr.
Heating	2	102990.6831	233.93	<.0001
Soaking	3	77004.2769	174.91	<.0001
Heating*soaking	6	7726.1108	17.55	<.0001
Error	24	-	-	-
CV%	5.18	-	-	-

Appendix 13 Mean squares of ANOVA for insoluble oxalate as affected by heating, soaking and interaction

Source	DF	Mean Square	F	Pr.
Heating	2	42582.28751	1702.82	<.0001
Soaking	3	15989.89398	639.42	<.0001
Heating*soaking	6	14635.66731	585.27	<.0001
Error	24	-	-	-
CV%	1.66	-	-	-

Appendix 14 Mean squares of ANOVA for proportion of soluble oxalate to total oxalate as affected by heating, soaking and interaction

Source	DF	Mean Square	F	Pr.
Heating	2	28.5052082	6.02	0.0076
Soaking	3	88.5203407	18.69	<.0001
Heating*soaking	6	81.5544157	17.21	<.0001
Error	24	-	-	-
CV%	3.77	-	-	-

Appendix 15 Heating time and temperature combination.

Heating treatment	Time in minute/hour	Temperature in ℃
Boiling	20 min	100 ℃
Drying	15 hrs.	70 ℃

Appendix 16 Soaking solutions list, pH value, stored temperature & soaked time.

Solution	pH value	Temperature in ℃	Soaked time/hrs.
Lemon juice	2.01 ±0.1	28 ±2℃	48 hrs.
Ginger juice	3.59 ±0.5	28 ±2℃	48 hrs.
Ethanol	5.12 ±0.4	28 ±2℃	48 hrs.