

ADDIS ABABA UNIVERSITY  
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EFFECT OF PROCESSING ON SOME PHYSICOCHEMICAL AND  
ANTINUTRITIONAL FACTORS OF TARO (*Colocasia esculenta* (L.)  
Schott.) CULTIVARS GROWN IN, ETHIOPIA

BY  
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## **Abbreviations**

AARC	Areka Agricultural Research Center
ANOVA	Analysis Of Variance
AOAC	Association Of analytical Chemists
BD	Bulk Density
BW	Body Weight
CHO	Carbohydrate
CSA	Central Statistic Agency
DM	Dry Matter
EARO	Ethiopian Agriculture Research Organization
EC	Emulsion Capacity
EHNRI	Ethiopian Health and Nutrition Research Institute
ES	Emulsion Stability
FAO	Food and Agricultural Organization
FC	Foam Capacity
FGD	Focused Group Discussion
FS	Foam Stability
GDP	Gross Domestic product
GE	Gross Energy
IAEA	International Atomic Energy Agency
MC	Moisture content
NRCS	National Resource Conservation Center
NRI	Natural Resource Institute
OAC	Oil Absorption Capacity
R&T	Root and Tuber
SNNP	South Nations and Nationalists People
SPSS	Statistical Product for System Solutions
SP	Swelling power
SSA	Sub Saharan Africa
TAN	Tropical Ataxic Neuropathy

TTA	Titrateable acidity
UNIFEM	The united Nations Development Fund for Women
USDA	United State Department of Agriculture
WAC	Water Absorption Capacity

## **Abstract**

Two cultivars of taro (*Boloso I* and *Acc.236000*) which were grown in Wollaita zone of Sothorn Nations, Nationalities and People Ethiopia were analyzed for their proximate composition, mineral composition, functional properties, and physicochemical properties and antinutritional factors composition. The effects of processing on these parameters were also determined. It was found that the range of values for raw sample; moisture content 0.54-0.92%, protein 5.83-9.14%, fat 0.35-1.05%, fiber 2.2-3.38%, total ash 4.46-5.44%, utilizable carbohydrate 82.88-85.65% and Gross Energy 370.5-375.1Kcal/100 g. From minerals studied; Fe, 5.86-6.08 mg/100g (db), Zn, 43.08-48 mg/100g (db), Mg, 7.24-7.32mg/100g. Among the functional properties, water and oil absorption capacity ranged from 1.85-3.82 and 0.9-1.63 ml/g, respectively; bulk density 0.69-0.88 g/ml, emulsion capacity 10.6-35.6ml/g, emulsion stability 7.4-12.9 ml/g and foaming capacity 7.4-12.9 ml/g. Values for some physicochemical properties include ; pH 4.92-6.44, TTA 0.32-1.71%,. The range of values for the antinutritional factors for raw sample Phytate 117.4-135.3mg/100g, Oxalate, 243-265.9mg/100g, Tannin, 47.69-59.92mg/100g, and Cyanide was not detected in any of the cultivars studied. There was significance difference ( $p < 0.05$ ) in the proximate composition between the two cultivars, antinutritional factors, some functional properties. Processing methods significantly affected the proximate composition of both cultivars. Boiling decreased the protein content of taro by 1.00-9.37%, but fermentation increased the protein content by 8.46-16.50%. The highest reduction of phytate about 86.6% was seen due to fermentation process. Boiling of taro resulted in highest reduction of oxalate (73.4%). The result indicated that fermentation was effective in the reduction of phytates from taro whereas the traditional processing, boiling was effective in the reduction of oxalate. Therefore, from the present study it can be concluded that no processing method is equally effective in reducing the antinutritional factors. From the two cultivars used in the present study *Acc.236000* was more affected by the processing method in terms of all parameters studied than *Boloso I*.

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Key words: *colocasia esculenta*, antinutrients, fermentation, boiling, oxalate.

# **1. INTRODUCTION**

## **1.1 Background of the Study**

Root and tuber crops are used as staple food in most countries in the world but their contribution to the energy supply of the population varies within a large range depending on the country (0 to 56% with a world mean of 5). Many species and varieties are consumed but three species (namely; cassava, Irish potato and sweet potato) provide 93% of the root and tuber (R&T) crops used for direct human consumption in the world. Some species are restricted in limited areas but the greatest; numbers of them are widespread by the mere fact that they have been diffused by men outside their origin area during the two last millenaries. The dispersion was mainly performed during the last five centuries by the Portuguese as they travel in search of slaves, by both the Portuguese and Spanish during their missionary journeys and by Arab traders (FAO, 1990).

Root crops are cheap, readily available and essential energy source for many poor people who face problem of food availability. Although they contain little protein, or fat some particularly sweet potato and yam, are source of vital vitamins (A and C) (UNIFEM, 2002).

The main advantages of root crops as a staple food compared with cereals are that they are cheaper source of energy, can be cultivated easily and provide more dietary energy per hectare at a lower cost (principally because of reduced labor inputs). They generally require a comparatively low level of husbandry (UNIFEM, 2002).

Many of the developing world's poorest producers and most undernourished households depend on root and tuber as a contributing, if not principal, source of food and nutrition. In part, these farm households value root and tuber because root and tuber produce large quantities of dietary

energy and have stable yields under conditions in which other crops may fail root and tubers produce remarkable quantities of energy per day, even in comparison to cereals. Potatoes lead the way in energy production, followed by yam. In addition, some root and tuber are an important source of vitamins, minerals, and essential amino acids such as lysine (Scott, *et al.*, 2000).

In many parts of Sub-Saharan Africa (SSA), root and tuber are a major source of sustenance. They account for 20 percent of calories consumed in the region (Gregory J. Scott, *et al.*, 2000). In developing countries, root and tubers are very important, especially in the food system of remote, generally marginalized areas, with particular low-income levels (Yared, 2007).

Under traditional farming system, root and tuber crops have some advantage over other sources of carbohydrates. They produce highest yield of calories per unit of land area, the yield are stable under conditions where other crops may not succeed, and they are cheap to produce. Besides being a source of carbohydrates, root and tuber crops contains proteins and vitamins and serve as security crop, alleviating seasonal shortage of foods caused by natural or man-caused disasters. Yared, (2007), pointed out that, root and tuber crops play multi-purpose roles in the global food system as a starch supplier, food security crop, source of cash income, raw material for feed and processed products, and as key components in small-scale agro-enterprise development.

The relative importance of individual root crops varies both by region and country. For example yams are a major food crop in West Africa, the Caribbean, the south Pacific Islands, South-East Asia, India and some parts of Brazil. Cassava is particularly important in South America, west East, Central and South Africa and Oceania. Taro plays an important cultural role in the diet of the people of the pacific Islands, West Africa, Oceania and the West Indies (UNIFEM, 2002).

Taro is referred to botanically as *colocasia esculenta* (L) Schott. It is vegetatively propagated, perennial tropical crop with a large peltate (“shield-shaped”) or heart-shaped leaves, in contrast to *xanthosoma* whose leaves are hastate (“spear shaped”) or arrow shaped. *Colocasia* and *xanthosoma* are together called cocoyams in many parts of the world, especially in Africa, old cocoyam for *colocasia* and new cocoyam for *xanthosoma*. In the Pacific regions, both genera are known as “taro”. However both genera appear to be cultivated in Ethiopia where they are known without differentiating between them as “Godere” (Amharic) and “Boina” (Wolaitigna) (Simon, 1992).

Taro starch is one of the most nutritious, easily digested foods. Similar to many other root crops taro corms are high in carbohydrate in the form of starch and low in fat and protein. The starch is 98.8 percent digestible, a quality attributed to its granule size, which is a tenth that of potato, making it ideal for people with digestive difficulties. The corm is an excellent source of potassium (higher than banana), carbohydrate for energy, and fiber. When eaten regularly, taro corm provides a good source of calcium and iron. Taro leaves eaten as a vegetable are excellent sources of provitamin A carotenoids, calcium, fiber, and vitamins C and B<sub>2</sub> (riboflavin), and they also contain vitamin B<sub>1</sub> (thiamin) (John J, 2007).

Taro contains about 7% protein on a dry weight basis. This is more than yam, cassava or sweet potato. The protein fraction is low in histidine, lysine, isoleucine, tryptophan, and methionine, but otherwise rich in all the other essential amino acids (FAO, 1999).

The taro leaf, like other higher plant leaves, is rich in protein. It contains about 23% protein on a dry weight basis. It is also a rich source of calcium, phosphorus, iron, Vitamin C, thiamine, riboflavin and niacin, which are important constituents of human diet (FAO, 1999). Taro is rich

in energy or carbohydrate, low in fiber and a fair source of fat and oils. When it is compared to Tannia and other root crops it has highest content of Phosphorus, Magnesium, and Zinc.

Like most plant origin foods taro also contains a variety of anti-nutritional and toxic components. Taro contains oxalates, phytates trypsin and amylase inhibitors, phytates, tannins and cyanide in some cultivars. Therefore is very important to processes taro before consumption.

## **1.2 STATEMENT OF THE PROBLEM**

Taro is a good source of nutrients that are important to human being however, it is underutilized in the Ethiopian context. This is attributed partly to the presence of inherent antinutritional factors such as oxalates and phytates, and to the less availability of effective methods of processing the raw taro in to a more acceptable and prolonged shelf life processed product. All parts of the taro plant contain acrid principles which are irritating the mouth and esophagus (Wilfred, 1999). All parts of taro can cause stomach aches, if ingested without cooking. Contact with the sap can irritate sensitive skin. If taro is not processed and cooked well; the acidity will cause itchiness in the mouth and throat (USDA NRCS, 2006). Acrid component may cause temporary sterility and has been directly linked to death of children. These effects have been proved using many experimental and domestic animals (Emmanuel-Ikpeme1, 2007).

Acridity has been attributed to the presence of bundles (called raphides) of calcium oxalate crystals in the taro tissues. Presumably, itchiness arises when the crystals are released and inflict minute punctures on the skin when in contact with it. More recent evidence Bradbury & Holloway, (1988) suggests that the crystals have to interact with a certain chemical on the raphide surface before acidity is experienced. These acrid substances can be present in the corn

(skin and flash) and leaves. They can occur either in the form of soluble oxalic acid or in the form of insoluble salts (Savage, and Dubois, 2006; Jrrarat *et al.*, 2006). Studies shows that eating a high-oxalate-containing food may contributed to the formation of kidney stones (Savage and Dubois, 2006). Continuing consumption of taro with a high oxalate salt can lead to gallstone deposition in the gall-balder (Jrrarat *et al.*, 2006). Soluble oxalic acid can form complexes with calcium, magnesium, or potassium and hence reduces mineral availability in the diet. It also been reported that insoluble oxalate salts can cause skin irritation and pungent odor in unwashed taro corms (Jrrarat *et al.*, 2006).

As many other root crops and cereals, taro also contains large amount of phytate (855mg/100g). Phytate is a storage form of phosphorus which is found in plant seed and in many root and tubers. Phytic acid has a potential to bind calcium, zinc, iron, and other minerals, thereby reducing their availability in the body. In addition, complex formation of phytic acid with proteins may inhibit enzymatic digestion of protein (FAO, 1990).

Some cultivars of taro also contain small quantity of cyanide. It contains about 1-5% of cyanide content of cassava (Bradbury and Sylvia, 1995).

According to central statistics agency substantial quantity of taro produced and consumed in Ethiopia (CSA, 2008), yet very little is known about the proximate composition (except analysis conducted by EHNRI in 1997), the level of antinutritional factors and processing methods that are effective in reducing these factors.

Therefore this research will be an important step in providing the necessary information concerning the level of oxalates and phytate, effective processing methods in reducing these factors in taro. Moreover the research focused on how the different processing methods affect some physicochemical properties, of different taro cultivars grown in Ethiopia.

Understanding the level of antinutritional factors and processing methods that are effective in reducing these factors may significantly contribute in reducing health risk that are associated with consumption of taro. Moreover understanding the physicochemical and functional properties of flours from the raw and processed taro may help also us in fortification of taro flour with other flours and the development of value added products from taro.

Considering the importance of taro and the unparallel contribution of improved cultivars in the crop productivity, the present study was pursued with the following primary and specific objectives.

### **1.3 Objectives**

#### **1.3.1 General Objective**

- ❖ The overall objective of this research was to study the effects of some processing methods on some physicochemical properties, nutrient compositions and antinutritional factors of taro (*colocasia esculenta*) cultivars grown in Ethiopia.

#### **1.3.2 Specific Objectives Were to:**

- ❖ Evaluate the processing methods in the reduction/ elimination of the anti-nutritional factors
- ❖ assess the proximate composition of taro along with other properties
- ❖ Evaluate the type of cultivar which was affected more by processing method.
- ❖ Study the functional property and nutritional composition of taro flour in order to suggest alternative consumption of taro

## 2. LITERATURE REVIEW

### 2.1 Over View of Taro

#### 2.1.1 Taxonomy and description

The term taro is used to refer to *Colocasia esculenta* (L.) Schott. It should not be confused with the related aroid *Xanthosoma* spp. which is called tannia. In many parts of the Asia and Pacific region, the name for tannia is a modification or qualification of the name for taro. In some of the world literature, taro and tannia are collectively called cocoyams. The ensuing presentation here concerns itself with taro, *Colocasia esculenta* (FAO, 1999)

Taro belongs to the genus *Colocasia*, within the sub-family Colocasioideae of the monocotyledonous family Araceae. Because of a long history of vegetative propagation, there is considerable confusion in the taxonomy of the genus *Colocasia*. Cultivated taro is classified as *Colocasia esculenta*, but the species is considered to be polymorphic. There are at least two botanical varieties:

- i) *Colocasia esculenta* (L.) Schott var. *esculenta*;
- ii) *Colocasia esculenta* (L.) Schott var. *antiquorum* (Schott), which is synonymous with *C. esculenta* var. *globulifera* .

There are about 1000 recognized cultivars which are grown throughout the world (NRI, 1987). These are distinguished on the basis of corm, cormels, or shoot characteristics, or on the basis of agronomic or culinary behavior, (FAO, 1999) but these fall mainly into two groups: the *eddoe* type of taro, which has a relatively small corm surrounded by large well-developed cormels (and 42 chromosomes), and the *dasheen*, which has a large central corm and numerous but small

cormels arising from its surface (and 28 chromosomes). The two types of *C. esculenta* are frequently referred to as separate species in the literature, *C. antiquorum* and *C. esculenta*, but it is more generally accepted that the taros are a polymorphic species, *C. esculenta*, and under this classification the eddoe is *C. esculenta* var. *antiquorum* (syn. *C. esculenta* var. *globulifera*) and the dasheen is *C. esculenta* var. *esculenta* (NRI, 1987).

The name cocoyam in West Africa is used to describe both *Colocasia* and *Xanthosoma* although "old" cocoyam is sometimes used for the former and "new" cocoyam for the latter (Pamela and Coursey, 1984).



**Fig.2.1**Taro corms and cormels from different cultivars

## **2. 1.2 Origin and Distribution**

Taro originated in South Central Asia, probably in India or the Malay Peninsula. Wild forms occur in various parts of South Eastern Asia. From its centre of origin, it spread eastward to the rest of South East Asia, and to China, Japan and the Pacific Islands. From Asia, taro spread westward to Arabia and the Mediterranean region. By 100 B.C., it was being grown in China and in Egypt. It arrived on the east coast of Africa over 2,000 years ago; it was taken by voyagers, first across the continent to West Africa, and later on slave ships to the Caribbean. Today, taro is pan-tropical in its distribution and cultivation. The greatest intensity of its cultivation, and its highest percentage contribution to the diet, occurs in the Pacific Islands. However, the largest area of cultivation is in West Africa, which therefore accounts for the greatest quantity of production. Significant quantities of taro are also grown in the Caribbean, and virtually all humid or sub-humid parts of Asia (FAO, 1999).

## **2. 1.3 Agronomic practices**

Taro can grow in a wide range of soil from upland or dry land soils that are well drained, non-flooded soils to soils that are in high rainfall areas or saturated for prolonged periods of time (USDA NRCS, 2006). Taro can grow in areas where only rice can grow because of standing water during the growing season. The upland taro is usually grown on hillsides in soil that is marginal in fertility and productivity. Soils in these areas are usually well drained and friable. While lowland or wetland taro is usually planted in low-lying areas where there is an abundant supply of water. The soils in these areas are normally alluvial with high native fertility and production. But the best results are obtained on deep, well-drained, friable loams, particularly alluvial loams, with a high water-table; a pH of 5.5-6.5 (NRI, 1987). Upland taro production is

widespread in Ethiopia (Yared, 2007). Taro can grow in areas ranging from sea level to 1,800 m in elevation under daily average temperature of 21-27°C and rainfall of 2500mm annually (NRI, 1987 and USDA NRCS, 2006). In Ethiopia, taro has been observed to thrive well even at low elevation as low as 1500m.a.s.l in some areas including Boloso Sore (the place where the sample for this study brought), if it acquires sufficient moisture, which is evenly distributed during the growing season (Yared, 2007). Taro cannot tolerate frosty conditions. Partly because of its temperature sensitivity, so it is essentially a lowland crop (FAO, 1999).



(a)



(b)

**Fig. 2.2 Flooded (a), and upland (dry land) (b), taros**

The maturation period varies according to the cultivar, and ranges from 6 to 18 months. Taros are ready for harvesting when the leaves begin to turn yellow and start to wither (NRI, 1988).

#### **2.1.4 World Production and Trade**

Data on world production and trade of edible aroids is difficult to estimate because of their very limited significance in terms of total production of root and tuber crops. Estimated world

production in 1988 was around 5.5 million Mt, and constituting about 3.3% of all root crops. World Taro production in 1994 was 5.8 billion kg; China harvested 1.4 billion kg, Hawaii 2.8 billion kg (Linwood A. Seaver, 2000). In 1998, about 6.6 million tones of taro/Tania were produced in the world on an area of 1.07 million hectares (the statistics combine taro and Tania). The bulk of the production and area were in Africa, with Asia producing about half as much as Africa, and Oceania about one tenth as much. The major producers in Asia were China, Japan, Philippines and Thailand; while in Oceania, production was dominated by Papua New Guinea, Samoa, Solomon Islands, Tonga and Fiji. This shows that world production and consumption is increasing (FAO, 1999).

Total world production area of taro alone was estimated to be about  $993 \times 10^3$  ha in 1983, with 80% in Africa. During this period, global production of taro was 5.607 million Mt, with about 61.33% in Africa and 38.67% in Asia. Estimates made about a decade ago indicated that total world production of the major edible aroids (taro and Tania) was about 5.23 million Mt in an area of 983 million ha, with average yield of  $5314 \text{ kg} \cdot \text{ha}^{-1}$  (FAO, 1991). Production declined by 5.3% from 5.64 million Mt in the 1979-81 periods to 5.34 Mt in 1989. Current statistics indicates that taro production increased slowly during the past 5 years from 5.6 million to 8.8 million Mt (Table 2. 1). Although exports increased by over 23% in volume, the value of exports remained fairly uniform over this period. Farmers and exporters interested in future business must ascertain the factors contributing to this trend and the potential impacts on business.

**Table 2.1 World production and trade of taro in the year 1995-2000**

	2000	1999	1998	1997	1996	1995
Production(Mt)	8,834,796	8,823,625	8,697,133	6,621,519	5,977,828	5,586,372
Exports, Quantity(Mt)	-	108,845	108,067	90,881	101,670	88,099
Exports, value (1000USD)	-	70,840	88,245	73,710	80,971	70,420

Source: FAOSTAT, 2000

In Ethiopia, according to CSA, 2,882,637.27 quintal of taro (“GODERE”), was estimated to be produced by, 1,285,870 holders in a total area of 38,285.96 hectares of land for the meher season of 2007/2008 (2000 E.C) (CSA, 2008).

**Table 2.2 World production of taro by region**

	<b>Production (1,000 tones)</b>	<b>Yield (tones/ha)</b>	<b>Area (1,000 ha)</b>
<b>World</b>	6586	6.2	1070
<b>Africa</b>	4452	5.1	876
<b>Asia</b>	1819	12.6	144
China	1387	16.8	82
Japan	255	11.6	22
Philippines	118	3.4	35
Thailand	54	11.0	5
<b>Oceania</b>	<b>283</b>	<b>6.2</b>	<b>46</b>
Papua New Guinea	160	5.2	31

	W. Samoa	37	6.2	6
	Solomon Islands	28	21.9	1
	Tonga	27	6.4	4
	Fiji	21	14.7	1

Source: FAO, 1999

## **2.2 Importance of Taro in Ethiopian Agriculture**

Agriculture is the backbone of the Ethiopia's economy. It contributes about 50 percent of the gross domestic product (GDP), 60% of exports, provides a livelihood for 85 percent of the total population and generates nearly 90 percent of foreign exchange earnings .Although this is the fact the country suffers from serious food shortage and recurrent drought (<http://www.wikipedia>, 2009).

Ethiopia with its diverse agro-ecologies and suitable environments, allows the growth of numerous root and tuber crops; mostly in the South and Western parts of the country by smallholder farmers (Asfaw, 2005). However, the majority of the Ethiopian population depends mainly on cereal crops as their main food source. The food potentials of most horticultural crops particularly that of root and tuber crops have not been fully exploited and utilized, despite their significant contributions towards food security, income generation, resource base conservation. Despite the fact that the country faces a considerable amount of food shortages to feed the nation, which might be the result of low agricultural productivity, recurrent drought that occurs every two to three years and socio-political factors (EARO, 2000). The present inadequate use of root and tuber crops could be attributed to many factors of which, low investment in research, extension and training of farmers on the utilization of these crops could be the most important (EARO, 2000). Therefore, the country should have to give serious attention on integration of root

and tuber crops in to the feeding of the people, so that it can alleviate seasonal food shortage and help the country in achieving food security; hence, taro is among these strategic crops (EARO, 2000).

Some root crops like potato, sweet potato, and taro/”Godere” are among the list of major crops that are consumed across the country. These and other economic importance prompts the peasant holders to grow many of the root crops (CSA, 2008).

Root crops cover more than 1.54% of the area under all crops in the country. Potatoes, sweet potatoes and taro (“GODERE”) added 27.39%, 33.83% and 20.77% of the area to the root crops total. The same crops contributed 26.29%, 34.39%, 18.83% to the root production total in the same order (CSA, 2008).

As we can see in the table below (Table 2.3) the total area of land covered by taro increased from 29, 721 ha in 2006/2007 to 38,280 ha in 2007/2008 season this is an increase of 28.82% and the total production of taro has increased from 2,271,506 quintal in the season 2006/2007 to 2,882,637 quintal in season 2007/2008 this is about 26.9%. This indicates that more farmers are interested in production and consumption of taro.

**Table 2.3 Area covered and production of taro in Ethiopia in the meher season of 2006/2007& 2007/2008**

Season	Area covered in hectares	Production in quintal
2006/2007	29,721	2,271,506
2007/2008	38,280	2,882,637

Source: CSA, 2008

According to survey conducted by the central statistics agency (CSA), more than 1.2 millions of farmers are engaged in the production of taro “GODERE” throughout the country. The largest production and holders of taro are farmers of region SNNP and Oromia with 78.9% and 62.3% respectively. The highest yield of taro is also in the region SNNP, 81.11 quintal/hectare. This is much more than the national average of 66.19 quintal/hectare. Therefore good farming practice and high yielding cultivars from this region should be exchanged with other region to fully utilize the potential of the crop throughout all producing regions.



(a)



(b)

**Fig .2.3 Taro ready for harvest (a) and during harvesting (b) at AARC**

In Ethiopia taro is cultivated fairly and extensively in densely populated and high rainfall areas of the south and southwestern parts of the country and remained an important food source among the communities and plays critical roles in rural diets (Edossa *et al.*, 1995). In some cases it fills food shortage gaps during the months when maize and other foods run short and in year of drought (Simon, 1992).

**Table 2.4 Regional production, land coverage, No. of holders and yield of taro in Ethiopia in the meher season 2007/2008.**

<b>Region</b>	<b>No. holders</b>	<b>Area in hectare</b>	<b>Production in quintal</b>	<b>Yield quintal/he.</b>
SNNP	890787	28034.78	2273977.2	81.11
Gambela	8189	117.73	9381.19	80
Oromia	384174	10117.73	599160.08	59.22
Benushangul	2150	10.87	*	*
Ethiopia	1,285,870	38,285.96	2,882,637.27	66.19

Source: CSA, 2008

\*data was not found

In north Omo, Ethiopia, taro has been grown since time immemorial, but how and when it was introduced remains unclear (Simone, 1992). Farmers give many reasons why they grow cultivate taro. According to Edossa et al, 1995; taro cultivated because of its high yield, resistance to disease and pests wide ecological adaptation, ease of management, long period storage of tubers after harvesting and its availability for consumption (Yared, 2007).

According to the survey conducted by the central statistics agency (CSA) there is an increase of the production and utilization of taro “GODERE” in Ethiopia in the year 2006/2007 and 2007/2008 crop season.( Table2.3). This indicates that producing taro in the rural area is increasing.

Taro can successfully grow on waterlogged or a heavy soil. In some parts of the world, it is grown on land that is naturally swampy or poorly drained, permitting economic utilization of

land, which would otherwise be useless; a dasheen type of taro does best when grown in such types of soils. Therefore we can utilize such kind of lands in Ethiopia by planting taro.

## **2.3 Proximate Composition, Physicochemical and Functional Properties of Taro**

### **2.3.1 Proximate Composition**

It is often assumed that root and tuber crops have a poor nutritive value because the comparison of their nutrient content to other crops is usually made on a fresh weight basis as expressed in composition tables. In fact this way of comparison does not reflect the reality. The comparison of the proximate composition of root and tubers and cereals is shown in (Table 2.6). With regards to nutritional aspects, chemical composition of different foods should be compared considering them either in the state they are eaten or on a dry weight basis. In the everyday life, nobody eats dry uncooked rice or wheat grains. The dry matter content of drained cooked rice (22%) or macaroni (23%) is lower than this of most root and tuber usual consumption forms. Because of the diversity of consumption forms and their high fluctuation in dry matter content, the easier way to evaluate and compare nutrient content consists in considering it on a dry weight basis. On the other hand, as nutrient content of root and tuber crops changes depending on the varieties within each species and on cultivation practices (e.g., fertilizer, length of vegetative cycle), climate, soil and location.

Several root and tuber crops have very low dry matter content (oca, ulluco) but, for others, it goes beyond 30g/100g FW (achira, arrowroot, cassava, cocoyam(TARO), sweet potato) .Protein content of certain root and tuber crops (e.g., achira, cassava, arracacha) is very low, for few

others (Irish potato, yams), it varies within the same range than cereals. Except for certain sweet potato varieties, root and tuber crop fat content is very low, it is mainly composed lipids of the cell membrane. The low fat and relatively high fiber content of root and tuber crops explains that they have a slightly lower energy content than cereal crops (Serge, 1996).

The main economic parts of the taro plant are the corms and cormels, as well as the leaves. The fresh weight composition of the taro corm is shown in (Table 2.5). The fresh corm has about two-thirds water and 13-29% carbohydrate.

**Table 2.5 Proximate composition of Taro corm on fresh weight basis**

<b>Component</b>	<b>Content</b>
Moisture	63-85%
Carbohydrate (mostly starch)	13-29%
Protein	1.4-3.0%
Fat	0.16-0.36%
Crude Fiber	0.60-1.18%
Ash	0.60-1.3%
Vitamin C	7-9 mg/100 g
Thiamine	0.18 mg/100 g
Riboflavin	0.04 mg/100 g
Niacin	0.9 mg/100 g

Source: FAO, 1999

It is also a rich source of calcium, phosphorus, iron, Vitamin C, thiamine, riboflavin and niacin, which are important constituents of human diet. The fresh taro lamina has about 20% dry matter, while the fresh petiole has only about 6% dry matter.

Notwithstanding their high starch content, edible aroids have a higher content of protein and amino acids than many other tropical root crops. Protein quality is essentially the same for all aroids determined with lysine as first limiting amino acid (chemical score 57-70) (Bradbury, 1988).

Compared to other tropical roots, taro corms are moderately good sources of water-soluble vitamins, such as thiamin, riboflavin and ascorbic acid. (Huang, *et al.*, 2007).

**Table 2.6 Comparison between root and tuber and cereal proximate composition**

Food	Dry mater g/100g FW	protein	fat	A.CHO	fiber	Energy Kcal/100gDM
<u>Root and tubers</u>						
Cassava	32.3	2.76	0.62	86.9	7.9	364
Irish Potato	22.2	9.2	0.5	66.7	9.3	316
Sweet potato	30.8	5.3	1.95	78.2	10.2	351
Yam	31.1	6.4	0.42	72.8	17.9	318
Taro	25.4	6.3	0.79	88.2	3.1	362
<u>Cereal crops</u>						
Maize	87.5	9.8	4.34	73.9	10.5	374
Rice	86.9	8.3	2.53	85.2	2.6	397
sorghum	88.6	11.6	3.61	78.6	4.2	393
Wheat	86.8	13.5	2.30	70.2	11.9	355

Source: Serge Treche, 1996

In order to get full information about the nutritional value of taro is worthwhile to have a closer look at of all proximate components of taro. Therefore they are briefly discussed.

#### **2.3.1.1 Moisture content of taro**

Since taro is root crop its moisture content is very high and accounts two third of the total weight of the fresh crops (FAO, 1999). Moisture content of taro varies with variety, growth condition and harvest time. In general the moisture content of taro ranges from 60-83% (FAO, 1999, Huang, *et al.*, 2007).

#### **2.3.1.2 Protein content of taro**

Taro contains about 7% protein on a dry weight basis. This is more than yam, cassava or sweet potato. The protein fraction is low in histidine, lysine, isoleucine, tryptophan, and methionine, but otherwise rich in all the other essential amino acids. The protein content of the corm is higher towards the corm's periphery than towards its centre. This implies that care should be taken when peeling the corm; otherwise a significant amount of the protein could be lost in the peel. (FAO, 1999, Mbong *et al.*, 2006, Nip, *et al.*, 1989). The taro leaf, like higher plant leaves, is rich in protein. It contains about 23% protein on a dry weight basis (FAO, 1999).

#### **2.3.1.3 Fat content of taro**

As many other root and tuber crops the fat content of taro is very low and its fat content is mainly composed of the lipids of the cell membrane and it is also variable among cultivars. Generally the fat content of taro range from 0.3%-0.6 % ( Mbong *et al.*, 2006, Nip, *et al.*, 1989).

### 2.3.1.4 Carbohydrate

Taro is rich source of carbohydrate as other root and tuber crops available carbohydrate can ranges 33.3-77.8%, extractable starch 46.9-73.2% (Mbfong *et al.*, 2006). The composition of the carbohydrate fraction is shown in (Table 2.7), indicating that the predominant carbohydrate is starch. The starch itself is about four fifths amylopectin and one-fifth amylose. The amylopectin has 22 glucose units per molecule, while the amylose has 490 glucose units per molecule. The starch grains are small and therefore easily digestible. This factor makes taro suitable as a specialty food for allergic infants and persons with alimentary disorders. However, the smallness of the starch grains makes taro less suitable as a source of industrial starch. The starch in the corm is more concentrated at the corm base than at the corm apex (FAO, 1999).

**Table 2.7 Percentage composition of Taro corm carbohydrates**

Carbohydrate	%
Starch	77.9
Pentosans	2.6
Crude Fiber	1.4
Dextrin	0.5
Reducing sugars	0.5
Sucrose	0.1

Source: FAO, 1999

#### **2.3.1.4 Total ash content**

Taro contains fairly high amount of ash. From which it can be inferred it contain good mineral content. The ash content of taro ranged from 3.54%-7.78%, (Nijoku and Ohia, 2007 and Mbofung, *et al.*, 2006).

#### **2.3.1.6 Crude fiber**

In general crude fiber has many desirable functional properties. These include facilitating alimentary functions, helping in micro-component delivery and glucose metabolism and also slowing down the process of re-absorption of undesirable dietary components such as cholesterol (Sujak, *et al.*, 2005). Taro contains both dietary and non-dietary fiber. In a research conducted on six cultivars of taro in Cameroon and Chad it was found that the crude fiber content of taro ranges from 0.3-3.8% (Mbofung, *et al.*, 2006). In another study conducted in six cultivars of taro grown in American Samoa the total soluble and insoluble fiber of taro even a larger range from 5.02-9.01% (Nip, *et al.*, 1989).

#### **2.3.1.5 Mineral content of taro**

Taro is a good source of minerals including iron (8.66-10.8 mg/100g), calcium (31-132mg/100g), sodium (82-1521.34mg/100g), magnesium (118-415.07mg/100g), phosphorus (72.21-340mg/100g) and an excellent source of potassium (2271-4276.06mg/100g). Taro is also a faire source of other essential minerals zinc (2.63mg/100g), copper (1.04mg/100g) all the amounts are on dry weight basis. The high potassium to sodium ratio may be an additional benefit in the diet of patients with high blood pressure however; different researchers have been suggested that,

high potassium foods should be omitted in diet of people with renal failure (Nijoku and Ohia, 2007 and Huang *et al.*, 2007).

#### **2.3.1.6 Gross energy of taro**

Among the various tropical root crops, taro is one of the most efficient producers of calories. The Bun long variety produced in Hawaii has an energy value of 4.2 to 4.4 cal/g (moisture free basis) as compared to 3.9 cal/g for sweet potato, 3.5 to 4.5 cal/g for rice and 1.3 to 1.5 cal/g for cassava (Emmanuel-Ikpeme1, 2007).

### **2.3.2 Physicochemical properties**

#### **2.3.2.1 Tuber size**

Different sizes of taro have been reported and the size of taro corms varies depending on the cultivars, location of growth, growth conditions (whether fertilizer application or not), maturity of the plant during harvest and others. In a study conducted in Thailand the size of corms of taro found to be ranged from 200-1320g (Jrarat, 2006)

#### **2.3.2.2 pH value of taro flours**

The pH of taro flour was determined by Mbofung *et al.*, (2006) in six cultivars of taro grown in Cameroon and Chad and they found that the values varied from 6.2-7.1.

#### **2.2.2.3 Titratable acidity of taro flours**

Titrateable acidity of foods indicates the amount of acids present in foods (John, 2007). TTA of taro flours was investigated by Mbofung *et al.*, (2006) and were found to be in the range of 0.68%-0.99%.

### **2.3.3 Functional Properties**

Functional properties indicate the ability of the flours to hold oil or fat and water, to emulsify the same and to form products having a firm consistency upon heating and cooling. These include viscosity, dispersibility, emulsify, form gels, foam, produce films and absorb water and/or fat. These are important tools in the formulation of the so-called “fabricated foods”. Since these functional properties of the flour are desired characteristics in many applications, as for example in food recipes (e.g. in meat, dairy and bakery products) and in industrial applications (e.g. in the paper coating industry), the enhancing of these properties in low functional proteinaceous materials is thus of substantial economic and technological importance. Functional properties related to water protein interactions protein isolates depend on the structural and aggregation characteristics of their major components. The functional properties of food proteins depend mainly on constituent amino acids and their sequences. To improve the functional properties, it is necessary to change the amino acid compositions and/or sequences. The functional properties of a protein in a food system are affected by source, composition, prior treatment and interaction with the physical and chemical environment (Assefa, 2008).

Functional properties are very important in determining the level of utilization in ingredient formulation and new food product development (Fasasi, 2007)

As described by Elevation E. Perez Sira, (2000), before consideration is given to tubers as potential sources of flour and starch to produce foods, it is necessary to characterize their chemical composition, physical, physicochemical, and functional properties. The chemical composition of flours and starches exhibits differences especially in amylose and phosphorous content, as a function of the botanical origin. It is significant because of the influence of amylose and phosphorous content in the functional properties of flours and starches. It is a general consensus

that the influence of both amylose and phosphorous content affects the gelatinization and pasting behavior of starches and flours. These two parameters determine the functional properties of flours and starches such as: texture, consistency, binding, coating, adhesiveness, cohesiveness, thickening, viscosity, and palatability.

Functional properties of starches and flours are dependent on botanical sources, composition of amylose and amylopectin and phosphorus contents (Sira, 2000).

### **2.3.3.1 Water and Oil Absorption**

The ability to absorb water is a very important property of flours used in food preparation. The ability of food materials to absorb water is sometimes attributed to the protein content (Mbfung *et al.*, 2006). WAC is an important functional property required in food formulations especially those involving dough handling (Udensi1, *et al.*, 2008). WAC plays a major role in the functionality of dough. In particular, WAC has been shown to be related to dough consistency (Njintang, *et al.*, 2008).

It is known that water binding by starches and flours is a function of several parameters including size, shape, conformational characteristics, steric factors, hydrophilic-hydrophobic balance in the starch molecule, lipids and carbohydrates associated with the proteins, thermodynamic properties of the system (energy of bonding, interfacial tension, etc.), physicochemical environment (pH, ionic strength, vapor pressure, temperature, presence/absence of surfactant etc.), solubility of starch molecules and others (Shimelis, *et al.*, 2006).

### **2.3.3.2 Bulk density**

Bulk density gives an indication of the relative volume of packaging material required. Generally, higher bulk density is desirable for the greater ease of dispersibility and reduction of paste thickness which is an important factor in convalescent child feeding [Udensi, and Okoronkwo, 2006)

### **2.3.3.3 Emulsion Capacity and Stability**

The formation and stability of emulsion is due to positive ions, which stabilized the negative charges of micelles. In this respect, it was thought that the presence of proteins ions would favor emulsion stability (Mbofung *et al.*, 2006).

### **2.3.3.4 Foam Capacity and Stability**

Stable foams are known to occur when low surface tension and high viscosity occur at the interface, forming a continuous cohesive film around the air vacuoles in the foam. Soluble proteins in general play an important role in the formation of foam and this probably justify why legumes exhibit higher foaming capacity (Mbofung *et al.*, 2006)

### **2.3.3.5 Swelling Power and Solubility**

Swelling power provides evidence of non-covalent bonding between starch molecules. Factors like amylose-amylopectin ratio, chain length and molecular weight distribution, degree/length of branching and confirmation determine the degree of swelling and solubility (Subramony, 2002).

### **2.3.3.6 Solubility**

Solubility of flours depends on a number of factors such as sucrose, inter-associative forces, swelling power, presence of other factors, etc (Subramony, 2002).

## **2.4 Antinutritional Factors**

### **2.4.1 Naturally Occurring Antinutrients, Toxic Substances and Their Negative Impact on Humans**

One major factor limiting the wider food utilization of many tropical plants is the ubiquitous occurrence in them of a diverse range of natural compounds capable of precipitating deleterious effects in man and animals. Compounds, which act to reduce nutrient utilization and/or food intake, are often referred to as antinutritional factors. Although toxic compounds are widely distributed in the plant kingdom, it is generally considered that tropical legumes contain a more complex array of these substances than any other crop species. These toxic compounds may occur in all parts of the plant, but the seed is normally the most concentrated source. Food crops regularly eaten have many beneficial nutrients but there are traces of antinutritional components such as cyanoglucosides, oxalates, phytic acid, phenolics, protease inhibitors, heavy metal etc. These antinutritional factors when consumed in foods may have adverse effects on health through inhibition of protein digestion, growth, and Fe and Zn absorption. (Omoruyi and Dilworth, 2007).

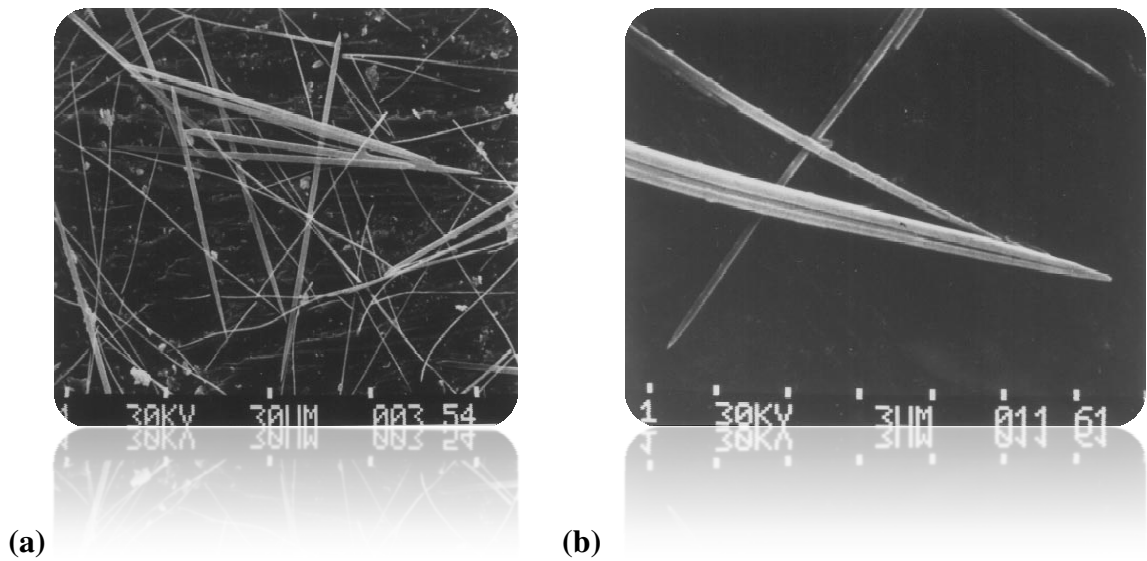
Root crops, in common with most plants, contain small amounts of potential toxins and antinutritional factors such as trypsin inhibitors, amylase inhibitors. Apart from cassava, which contains cyanogenic glycosides, cultivated varieties of most edible tubers and roots do not contain any serious toxins. Wild species may contain lethal levels of toxic principles and must be correctly processed before consumption (FAO, 1990). Taro contains antinutritional factors such

as: oxalates, tannins, phytates, trypsin inhibitors, amylase inhibitors and in some cultivars cyanide.

#### **2.4.1.1 Oxalates**

One major limiting factor in the utilization of taro is the presence of oxalates which impart acrid taste or cause irritation when foods prepared from them are eaten. Ingestion of foods containing oxalates has also been reported to cause caustic effects, irritation to the intestinal tract and absorptive poisoning. Oxalates are also known to interfere with the bioavailability of calcium (Samuel, and Emmanuel, 2004).

Most taro cultivars taste acrid and can cause swelling of lips, mouth and throat if eaten raw (Bradbury & Nixon, 1998). This acidity is caused by needle-like calcium oxalate crystals (Fig.2.4), raphides (*raphides are structures formed as needle-shaped crystals of calcium oxalate in plant cell vacuoles*) that can penetrate soft skin (Bradbury & Nixon, 1998). Thereafter an irritant present on the raphides, probably a protease can cause discomfort in the tissue (Bradbury & Nixon, 1998). Both the root and the leaves can give this reaction (FAO, 1992) but this effect is reduced by cooking (Bradbury & Nixon, 1998). Cooking can affect the soluble oxalate but not the insoluble oxalate content of the food. Boiling can reduce the soluble oxalate content of a food if the cooking water is discarded, while soaking, germination and fermentation will also reduce the content of soluble oxalates (Noonan & Savage, 1999). In contrast, baking a food will cause an effective concentration of oxalates in the food due to the loss of water from the baked food (Noonan & Savage, 1999).



**Fig. 2.4 Thin (a) and thick (b) calcium oxalate crystals (raphides) isolated from Taro**

**Source:** Bradbury & Nixon, (1998)

Oxalic acid is a common and wide spread constituent of plants, being found in almost all plant families usually at low levels. It occurs as the free acid, as soluble salts of potassium and sodium and as insoluble salts of calcium, magnesium and iron (Noonan & Savage, 1999). High oxalate concentrations in the leaves and corms of plants consumed daily are of concern because of the harmful health effects associated with the intake of high amounts of oxalates (Savage and Catherwood, 2007).

Oxalic acid forms water soluble salts with  $\text{Na}^+$ ,  $\text{K}^+$  and  $\text{NH}_4^{2+}$  ions and it also binds with  $\text{Ca}^{2+}$ ,  $\text{Fe}^{2+}$  and  $\text{Mg}^{2+}$  and rendering these minerals unavailable to animals. However Zn appears to be relatively unaffected (Noonan and Savage, 1999). Calcium oxalate crystals occur in more than 215 higher plant families, as well as the algae, lichen and fungi, in the form of whewellite ( $\text{CaC}_2\text{O}_4 \cdot \text{H}_2\text{O}$ ) or weddelite ( $\text{CaC}_2\text{O}_4 \cdot 2\text{H}_2\text{O}$ ). They can form in any organ or tissue within plants, including in stems, leaves, roots, tubers, and seeds, and have a variety of functions including calcium storage, defense and providing structural strength (Alison , 2005).

The highest levels of oxalates are found in the following families: amaranth family for example *Amaranthus* (amaranth); aroid/arum family, for example *colocasia* (Taro) and *Xanthosoma* (caladium), *goothfoot* family, for example, *Atriplex* (orach), *Beta* ( beet, beetroot) and *Spinachia* (Spinach); ice-plant family for example, *Tetragonia* (NZ spinach); Wood sorrel family for example *Oxalis* (sorrel yam); buckwheat family, for example, *Rheum* (rhubarb) and *Rumex* (sorrel); and the purslane family, for example *portulaca* (purslane) (Noonan and Savage, 1999).

The oxalic acid content is variable within some species; some cultivars of spinach contain 400-600mg/100g, while others range from 700-900mg/100g. Oxalic acid accumulates in plants especially during dry season. The distribution of oxalic acid within plants is also uneven. In general, oxalic acid is highest in the leaves followed by seeds; it is lowest in the stems. High oxalate levels in tropical plants are of concern. Taro (*colocasia esculenta*) and sweet potato (*Ipomoea batatas*) were reported to contain 278-574mg/100g FW and 470mg/100g FW, respectively (Noonan and Savage, 1999).

High oxalate foods have been known to exert a negative effect on the absorption of calcium and iron. The adverse effect of oxalate is greater if the oxalate:calcium ratio exceeds 9:4. The adverse effect of oxalates must be considered in terms of oxalate: calcium ratio in the food. This ratio varies widely and can be classified into three groups: (i) plants with oxalate to calcium ratio of greater than 2, (ii) plants with ratio of approximately one and (iii) plants with a ratio of less than one (Noonan and Savage, 1999).

Foods that have a ratio greater than two and that contain no utilizable calcium have exceeds oxalates which can bind calcium in other food eaten at the same time. Foodstuffs having a ratio of approximately one do not encroach on the utilization of calcium provided by other products and, therefore, do not exert any demineralizing effects. However these foods are not good source

of calcium. Foods with a ratio of one do not reduce the availability of calcium as far as other calcium sources are concerned (Noonan and Savage, 1999).

Oxalates are poorly absorbed under non-fasting conditions. It has been demonstrated that only 2-12% of the oxalate is absorbed from foods but that once absorbed, free oxalates binds to calcium form insoluble calcium oxalate. This may result in a functional hypocalcaemia with tetany in acute cases. Free oxalate and calcium precipitate in the urine and may form kidney stones. These stones are comprised mainly of calcium oxalate (80%), which is relatively insoluble in urine, and calcium phosphate (5%). Oxalates crystallizes with calcium in the renal vasculature and infiltrates vessel walls causing renal tubular obstruction, vascular necrosis and haemorrhage, which leads to anuria, uraemia, electrolyte disturbances or even rupture.

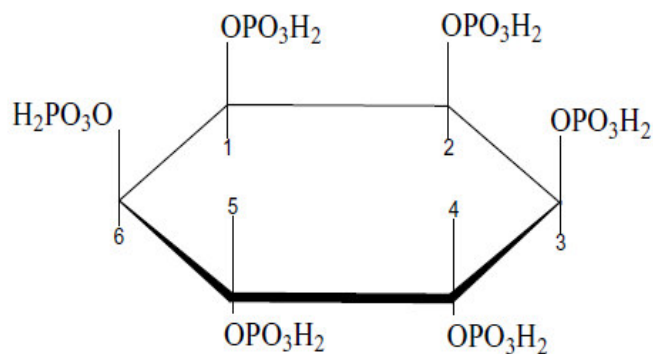
Oxalic acid may cause greater decreases in mineral availability if consumed with a high fiber diet, although the decrease may only be temporary. Negative calcium, magnesium, zinc and copper balances were detected in males consuming a diet containing fiber and oxalates (Noonan and Savage, 1999).

In order to counteract the deleterious health effects against consumption of high oxalate rich foods, there must be an effective method to reduce the amount of oxalate in foods.

#### **2.4.1.2 Phytates**

Phytic acid (myo-inositol hexaphosphate, IP6) or phytate is the primary storage form of phosphorus in plant seeds and is associated with fibre in many foods such as soy- and cereal-based products (Monica, *et al.*, 2005) Phytic acid is a major phosphorus compound in plant seeds and is also found in significant quantities in roots and tubers (Dilworth, *et al.*, 2005, FAO, 1990).

Phytate is regarded as the primary storage form of both phosphate and inositol in plant seeds and grains. In addition, phytate has been suggested to serve as a store of cations, of high energy phosphoryl groups, and, by chelating free iron, as a potent natural anti-oxidant (Greiner, *et al.*, 2006). It consists of an inositol, which is a hexahydroxycyclohexane in chair conformation, with six phosphate ester bonds. The phosphate groups confer on it a high negative charge and therefore a strong chelating ability (Dilworth, *et al.*, 2005). Phytate behaves in a broad pH-region as a highly negatively charged ion and has therefore a tremendous affinity for food components with positive charge(s), such as minerals, trace elements and proteins. There is a large body of evidence that minerals are less available from foods of plant origin as compared to animal-based foods (Greiner, *et al.*, 2006).

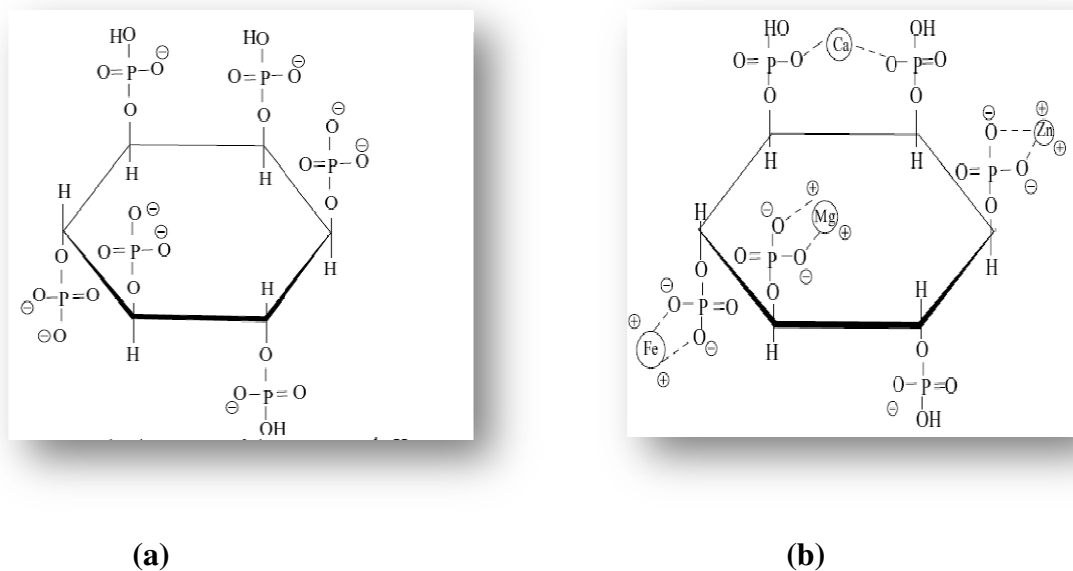


**Fig. 2.5 Molecular structure of phytate, source: (John, *et al.*, 2004)**

Phytic acid binds to essential minerals, thus rendering them unavailable for intestinal uptake and unable to participate in essential metabolic processes in the body. The ratio of phytic acid to minerals present in foods may serve as an indication of the availability of the minerals in question. For example, a high phytic acid to zinc molar ratio (> 15:1) indicates low mineral availability from that food (LL Dilworth, *et al.*, 2005). Minerals of concern in this regard would include Zn<sup>2+</sup>, Fe<sup>2+/3+</sup>, Ca<sup>2+</sup>, Mg<sup>2+</sup>, Mn<sup>2+</sup>, and Cu<sup>2+</sup> (Greiner *et al.*, 2006). Phytate exhibits high

affinity to all polyvalent cations in the following decreasing order of stability:  $\text{Cu}^{2+} > \text{Zn}^{2+} > \text{Ni}^{2+} > \text{Co}^{2+} > \text{Mn}^{2+} > \text{Fe}^{3+} > \text{Ca}^{2+}$  (John Shi, et al, 2004). According to Hurrell *et al.*, (1992), an intake of 4-9mg/100g DM phytic acid is said to decrease iron absorption by 4-5 fold in humans (Hurrell *et al.*, 1992).

Phytate has six reactive phosphate groups and meets the criterion of a chelating agent. In fact, a cation can bind to one or more phosphate group of a single phytate molecule or bridge two or more phytate molecules (Fig.2.6). Most phytates tend to be more soluble at lower compared to higher pH-values.



**Fig. 2.6 (a), Structure of phytate at neutral pH and (b), phytate metal complex**

Source: John, *et al.*, 2004)

The formation of insoluble metal cation-phytate complexes at physiological pH-values is regarded as the major reason for a poor mineral availability, because these complexes are essentially non-absorbable from the gastrointestinal tract. Most studies have shown an inverse

relationship between phytate content and mineral availability, although there are great differences in the behavior of individual minerals, Zn<sup>2+</sup> was reported to be the essential mineral most adversely affected by phytate (Greiner, *et al.*, 2006).

Human studies also indicated that phytate inhibits Ca<sup>2+</sup> absorption, but the effect of phytate on Ca<sup>2+</sup> availability seems to be less pronounced compared to that on the availability of iron and particularly Zn<sup>2+</sup>. This may be due to the relatively high Ca<sup>2+</sup> content of plant-based foods, the capability of the bacterial flora in the colon to dephosphorylate phytate and the fact, that Ca<sup>2+</sup> could be absorbed from the colon (Greiner, *et al.*, 2006).

Phytate is known to form complexes with proteins at both acidic and alkaline pH. This interaction may effect changes in protein structure that can decrease enzymatic activity, protein solubility and proteolytic digestibility. However, the significance of protein-phytate complexes in nutrition is still under scrutiny. Strong evidence exists that phytate-protein interactions negatively affect protein digestibility *in vitro* and the extent of this effect depends on the protein source (Greiner, *et al.*, 2006 and Greiner and Konietzny, 2006).

Of nutritional significance might be also the inhibition of digestive enzymes such as  $\alpha$ -amylase, lipase or proteinases, such as pepsin, trypsin and chymotrypsin, by phytate as shown in *in vitro* studies. This inhibition may be due to the non-specific nature of phytate protein interactions, the chelation of calcium ions which are essential for the activity of trypsin and  $\alpha$ -amylase, or the interaction with the substrates of these enzymes. The inhibition of proteases may be partly responsible for the reduced protein digestibility (Greiner, *et al.*, 2006).

Phytate behaves in a broad pH range as a highly negatively charged ion and has therefore a tremendous affinity for food components with positive charge(s), such as minerals, trace elements and proteins (Greiner and Konietzny, 2006)

As many other root crops and cereals, taro also contains large amount of phytate (855mg/100g) (FAO, 1990). In order to utilize the Taro as a food component of human nutrition and to evaluate the effect of phytate present in taro on the availability of mineral and protein, one should have to determine quantitatively the phytate level.

#### **2.4.1.3 Cyanide**

Hydrocyanic acid or HCN is a volatile compound. It evaporates rapidly in water in the air at temperature over 28°C and dissolves readily in water. It may easily be lost during transport, storage and analysis of specimens (FAO, 1990). The consumption of cyanide even at low levels over a long period can induce iodine deficiency, leading to goiter and (Sahoré, *et al.*, 2006).

Hydrogen cyanide inactivates the enzyme cytochrome oxidase in the mitochondria of cells by binding to the  $Fe^{3+}/Fe^{2+}$  contained in the enzyme. This causes a decrease in the utilization of oxygen in the tissues. Cyanide causes an increase in blood glucose and lactic acid levels and a decrease in the ATP/ADP ratio indicating a shift from aerobic to anaerobic metabolism. Cyanide activates glycogenolysis and shunts glucose to the pentose phosphate pathway decreasing the rate of glycolysis and inhibiting the tricarboxylic acid cycle. Hydrogen cyanide will reduce the energy availability in all cells, but its effect will be most immediate on the respiratory system and heart.

In animals, the lethal doses of HCN are generally reported to be between 0.66 and 15 mg/kg body weight (BW) for various species. Chronic sub-lethal dietary cyanide has reportedly caused some reproductive effects including lower birth rates and an increased number of neonatal deaths; impaired thyroid function; and behavioral effects including increasing ambivalence and slower response time.

Other long-term diseases related to dietary cyanide intake include (i) konzo, an upper motor neuron disease characterized by irreversible but non-progressive symmetric spastic paraparesis with an abrupt onset; (ii) tropical ataxic neuropathy (TAN), a term used to describe several neurological syndromes whose clinical features include optical atrophy; angular stomatitis; sensory gait ataxia; and neurosensory deafness; (iii) goiter and cretinism, which are caused by iodine deficiency, can be considerably aggravated by a continuous dietary cyanide exposure. These diseases occur in countries where there is chronic consumption of cassava as a staple food and dietary intake of protein and/or iodine are inadequate (Food Standards Australia New Zealand, 2005).

Cyanogenic glucosides are a major class of plant allelochemical present in the Araceae, and many other plant families. The cyanogenic glucoside, triglochinin, derived from tyrosine, was isolated and identified from the leaves of *Alocasia macrorrhiza*, from other species of Araceae and from *Arum*.

The amounts of cyanide present in *Colocasia* and *Xanthosoma* leaves, and the much smaller amounts present in the stems, are only about 1-5% of the amount present in cassava leaves and tubers and are not a cause of concern for human nutrition (Bradbury and Sylvia, 1995).

The much greater concentration of cyanogenic glucoside in the leaf as compared with the stem is consistent with the idea that the leaves are much more exposed to attack by predators than the stems (except for *Alocasia* where the stems are above ground), i.e. the leaves have a higher 'apparency' than the stem. It is interesting that in one taro cultivar there was no cyanogenic glucoside present, which indicates that this allelochemical defense mechanism is not used

universally in taro, but it was present in all seven cases of *Alocasia* studied (Bradbury and Sylvia, 1995).

Cyanide is detoxicated in the body by conversion to thiocyanate, a sulphur containing compound with goitrogenic properties. The conversion is catalysed by an enzyme thiosulphate cyanide sulphur transferase (rhodanase) present in most tissues in humans, and to a lesser extent by mercaptopyruvate cyanide sulphur transferase which is present in red blood cells. The essential substrates for conversion of cyanide to thiocyanate are thiosulphate and 3-mercaptopyruvate, derived mainly from cysteine, cystine and methionine, the sulphur-containing amino acids. Vitamin B12 in the form of hydroxycobalamin probably influences the conversion of cyanide to thiocyanate. Hydroxycobalamin has been reported to increase the urinary excretion of thiocyanate in experimental animals given small doses of cyanide.

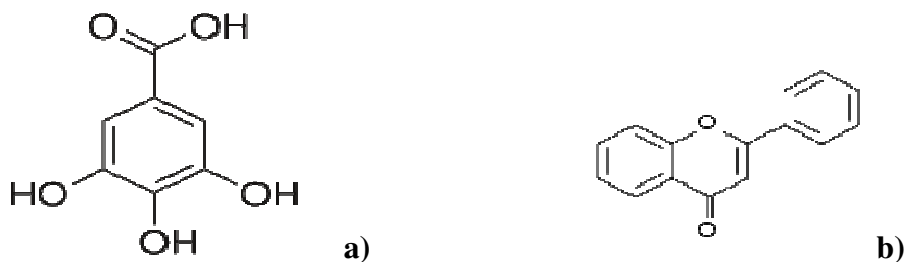
About 60 to 100 percent of the injected cyanide in toxic concentration is converted to thiocyanate within 20 hours and enzymatic conversion accounts for more than 80 percent of cyanide detoxification. Thiocyanate is widely distributed throughout body fluids including saliva, in which it can readily be detected. In normal health, a dynamic equilibrium between cyanide and thiocyanate is maintained. A low protein diet, particularly one which is deficient in sulphur containing amino-acids may decrease the detoxification capacity and thus make a person more vulnerable to the toxic effect of cyanide. Excessive consumption of foods which contains cyanide, such as cassava, as the sole source of dietary energy and main source of protein, could thus increase vulnerability to cyanide toxicity (FAO,1990).

#### 2.4.1.4 TANNINS

Tannins are water soluble phenolic compounds having molecular weights between 500-3000 giving the usual phenolic reactions and having special properties such as the ability to precipitate alkaloids, gelatin and proteins. The dark color and astringent taste of food is often ascribed to tannins. They can have a large influence on the nutritive value of many foods eaten by humans such as vegetables, fruits, chocolate, tea, alcoholic and non-alcoholic beverages, etc. Foods rich in tannins are considered to be of low nutritional value because they precipitate proteins, inhibiting digestive enzymes and Fe absorption and affect the utilization of vitamins and minerals from meals (Tinko and Uyano, 2001).

They are readily form indigestible complexes with proteins and other macro-molecules under specific environmental conditions. Tannins had been reported to affect protein digestibility, adversely influencing the bioavailability of non-haem iron leading to poor iron and calcium absorption, also carbohydrate is affected leading to reduced energy value of a diet containing tannins (Adeparusi, 2001).

Tannins are very important commercial products. However, their chemistry is very complex and diverse. They can be classified into two groups, the proanthocyanidins (or condensed tannins) and the polyesters of gallic acid and (or) hexahydroxydiphenic acid (hydrolysable tannins, respectively, gallo- and ellagitannins) (Mahmut and Ayhan, 2002). Condensed tannins are derivatives of flavanols and hydrolysable tannins are esters of a sugar, usually glucose (Lau, *et al*, 2002). The co-occurrence of both kinds of tannins in the same plant or plant tissue is often observed. Tannins are found in the leaves, fruits, barks, roots and wood of trees (Mahmut and Ayhan, 2002).



**Fig.2.7 Basic structure of hydrolysable (a), and condensed (b) tannins.**

## **2.5 Methods to reduce/ eliminate antinutrients in taro**

In order to minimize the deleterious health effects associated with the consumption of antinutritional and toxic components in food researches have been working to reduce the level of these substances using different methods. These methods includes breeding, biotechnology, and effective processing methods such as, cooking, fermentation roasting, extrusion cooking,

### **2.5.1 Breeding as a means of reducing antinutrients**

Breeding of plants is a common means used in the plant research centers to increase the nutritional value of plants, to increase the pest resistance of the plant and to enhance the palatability and acceptability of the plant product by reducing factors that are responsible for undesired quality of the product. This usually done by selecting a good variety and breeding it with bad one.

### **2.5.2 Biotechnological techniques for antinutrients reduction**

Different biotechnological techniques have been used in different countries to enhance the utilization of taro and cocoyams in general including: development of high yielding taro, pest resistance, improved quality of test (reduced oxalate content), resistance to the fungal disease

development of early maturing and disease resistant plant using gamma radiation, application of biotechnology and mutation (IAEA, 2004).

### **2.5.3 Process methods for reduction of antinutrients**

Processing method is one of the most common and widely used methods in the reduction of antinutrients from foods. Foods processing is aimed at reducing the toxic substances in food, increasing the palatability of foods, increasing the shelf life of foods, and minimizing the post harvest losses. There are different kinds of processing methods that are effective in reducing antinutritional factors in plant foods. These may includes; extruder cooking, germination, roasting, soaking, boiling, fermentation.

#### **2.5.3.1 Boiling**

Boiling is effective method in reducing water soluble antinutrients. For example boiling of root crops such as taro and cassava will lead to significant reduction of oxalates and cyanide respectively. Boiling also found to decrease some amount of soluble phytate. Since boiling needs energy it is not economical method as other processing methods such as natural (spontaneous fermentation) for poor rural community.

#### **2.5.3.2 Natural Fermentation**

Fermentation is one of the oldest, simple and most economical methods of producing and preserving foods. It is well known that lactic acid fermentation, mostly applied at the household level in African countries, may provide away to reduce volume of material to be transported, to

enhance nutritive value, to improve appearance and taste of some foods to salvage materials otherwise not suitable for human consumption, to reduce energy required for cooking and to destroy antinutritional compounds of foods (Agbor, et al., 1995)

Food fermentation covers a wide range of microbial and enzymatic processing of food and ingredients to achieve desirable characteristics such as prolonged shelf life, improved safety, attractive flavor, nutritional enrichment, and elimination of anti-nutrients and promotion of health. Many cereals, legumes and vegetables are extensively used in the preparation of a variety of fermented foods. Microorganisms used for food fermentation may be part of the natural microflora found in the raw material that is fermented or specially cultivated cultures designed to bring about specific changes in the material that is being fermented. Today, defined starter cultures and controlled conditions are generally used in food fermentation. The type of microorganism, the fermentation conditions used, and the starting amount of phytate present in the raw material significantly affect the extent of phytate removal during the fermentation process. Major fermentation microorganisms include lactic acid bacteria, moulds and yeast (Greiner and Konietzny, 2006).

Fermentation of vegetables can occur “spontaneously” because of the natural lactic bacterial surface microflora, i.e., *Lactobacillus* spp., *Leuconostoc* spp., *Pediococcus* spp., etc.; however, the use of a “starter culture” provides consistency and reliability of performance, and *Lactobacillus plantarum* is the “starter” most frequently used in LA fermentation of plant materials ( Smita, et al., 2007).

The fermentation process of staples serves as a means of providing a major source of nourishment for large rural populations, and contributes significantly to food security by increasing the range of raw materials, which can be used in the production of edible products

(Adewusi *et al.*, 1999). Fermentation enhances the nutrient content of foods through the biosynthesis of vitamins, essential amino acids and proteins, by improving protein quality and fibre digestibility. It also enhances micronutrient bioavailability and aids in degrading anti-nutritional factors (Oboh, and Elusiyan, 2007).

The main advantage of natural fermentation processes is that they are fitting to the rural situation, since they were in fact created by it. Also, the consumer safety of several African fermented foods is improved by lactic acid fermentation, which creates an environment that is unfavorable to pathogenic *Enterobacteriaceae* and *Bacillaceae*.

Many fruits and vegetables contain naturally occurring toxins and antinutritional compounds. These can be removed or detoxified by the action of micro-organisms during fermentation (FAO, 1998).

### **3. Materials and Methods**

#### **3.1 Study Area**

The study was conducted in Areka, Boloso Sore district of Wollaita Zone found in the South Nations Nationalities and Peoples' Region (SNNPR). Boloso Sore district is located 415 kms south of Addis Ababa and 30 kms away from the zonal capital, Sodo. Areka, the district main town was chosen for this study for reasons of accessibility; the Areka Agricultural Research Center is also located in this town. This research center is working mainly in the root and tuber crops. The area is located at an altitude range of 1730 and 1830 m a.s.l. There is a high population density in the area which is estimated to be about 450 persons per km<sup>2</sup>. The area like most parts of the country has two periods of rainfall; the “big” and “small” rains of June to September and March to April, respectively, receiving an average annual rainfall of about 1528.1 mm. The average annual temperature is 19.5°C and the yearly maximum and minimum temperature is about 25.6 °C and 13.7°C, respectively. The population is predominantly Wollaita and agriculture is the main source of income in the area, where the farming system is characterized by small scale production of mixed crops and livestock. In this area, several root crops (yam, cassava, taro and sweet potato) as well as enset are planted soon after a “small” rain from April to June. Cereals, such as teff, wheat, maize and beans are also planted during the “big” rains, which last from June to September. From the dietary information, the major staple diets are maize and enset followed by sweet potato and a combination of maize and enset and maize and sweet potato.

## 3.2 Sample Collection, Transportation, Preparation and Storage

### 3.2.1 Sample Collection

Samples were collected from Areka Agricultural Research Center (AARC). All the samples were harvested within 8-10 months of planting, which is the maturation period of taro (NRI, 1987). The sampling technique used was judgment sampling method. Horticulturists who work in the research center had helped me in the selection of the samples. Fresh samples which were immediately harvested from the ground were selected based on the visual examination with the help of experienced persons who work in the area for many years. The taro samples selected contain large, middle, and small corm (cormels) sizes that were not damaged during harvest and they were not attacked by pests. About three kilograms from each size were collected.

Two kind of taro samples, Boloso I and Accession No. 236000 were collected (Fig. 3.1).



a)



b)

**Fig. 3.1** Cultivars of taro grown in Ethiopia, (a) Accession 236000 and (b) Boloso I

The samples were kept in an ice box at about 5°C and transported to Addis Ababa. After that, the same day the samples were weighed using a calibrated balance. Within 48 hours of harvest taro flours were prepared from all size of tubers separately following the procedure as indicated in Fig 3.1(a). Finally, the flours that were prepared from the three size groups were thoroughly mixed using a blender and were filled in polyethylene bags packed and kept in desiccators until needed for analysis.

### **3.2.2 Sample Preparation**

All the samples were cleaned manually to remove foreign matters adhering to it and hand peeled carefully using stainless steel knives and the peeled taro was washed and sliced. The slices were dried overnight in a hot air oven at 50°C . The dried taro chips were milled using an electric mill (CYCLOTEC, 1093 sample mill, Tecator, Sweden) and sieved to pass through 60 mesh sieve.

For raw taro analysis, the sliced and peeled taros were freeze dried using (LABCONCO, AJ461A, USA) freeze drier milled and sieved as indicated above.

#### **3.2.2.1 Flour Sample preparation for boiled taro samples**

Taro corms were carefully selected and cleaned to remove adhering materials and soils. Then they were thoroughly washed using a running tap water. About 500g of cleaned and washed taros were placed in cooking utensil and 1500ml of water was added to it and the cooking utensil was placed over a hot plate to boil for 45 min. The time of boiling was recorded after the water started to boil. After 45 min. the boiling water was discarded and the boiled tubers were allowed to drip dry. Then the tubers were hand peeled and sliced in to approximately 0.5mm thick and placed on a stainless stile tray and allowed to dry in oven at 50°C over night to a constant weight. The dried

taro chips were converted to flour using miller (CYCLOTEC, 1093 sample mill, Tecator, Sweden) and sieved to pass through 60 mesh sieves, following the procedure indicated in Fig.3.2

### 3.2.2.2 Flour Sample preparation for fermented taro flours

For fermentation, about 100g of taro flour was mixed with 300ml of distilled water in 1000ml conical flask and the flask was covered with aluminum foil and allowed to ferment naturally (spontaneously) at room temperature for 72 hours. After 72 hours of fermentation the slurry was transferred to glass bowls and placed in oven to dry over night to a constant weigh. Then the dried slurry was milled to flour using miller (CYCLOTEC, 1093 sample mill, Tecator, Sweden), sieved, packed and stored in a desiccators.

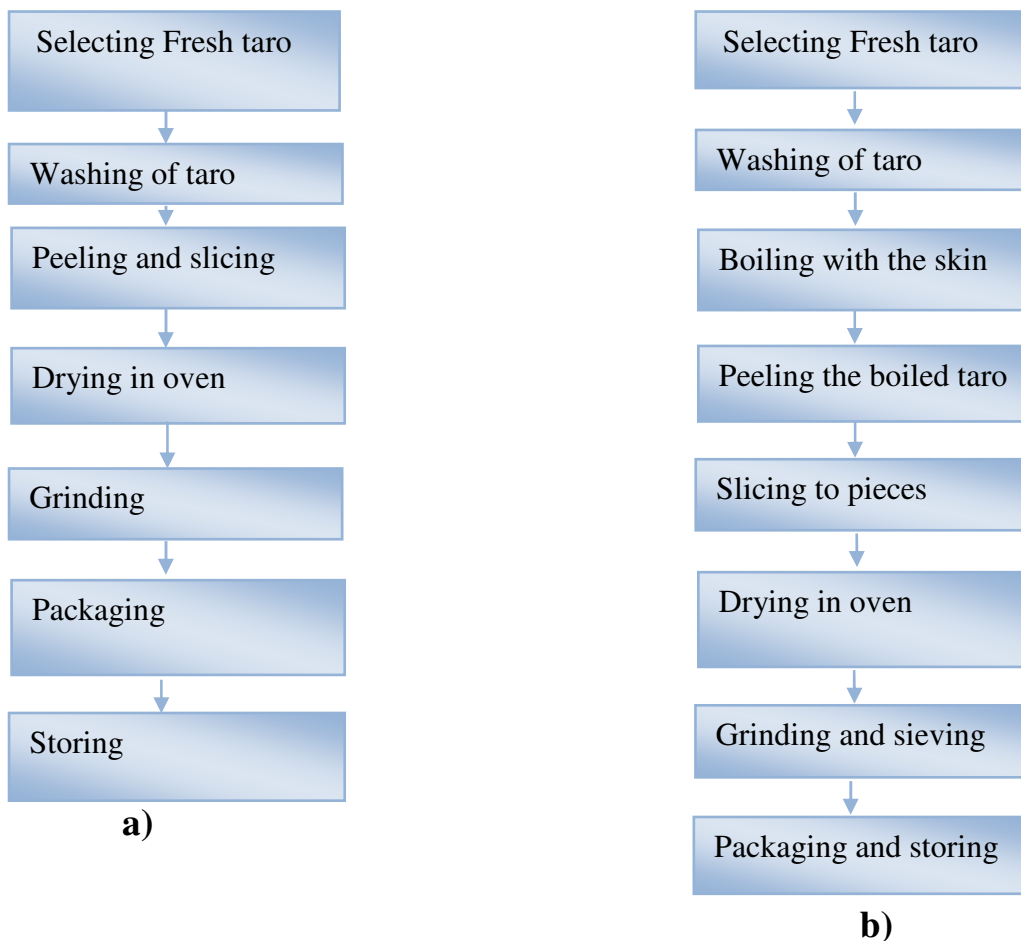


Fig 3.2 Flow diagram for the preparation of flours from raw, (a), and boiled,(b) taro flours

### 3.3 Analysis methods

#### 3.3.1 Proximate composition of taro cultivars

Moisture content, total ash, crude protein, crude fiber, and crude fat of the raw and blended flours were determined according to AOAC (2000) using the official methods 925.09, 923.03, 979.09, 962.09, and 4.5.01, respectively.

##### 3.3.1.1 Determination of crude protein

Protein content was determined according to AOAC (2000) using the official method 979.09. A digestion flask containing about 1 g of sample, to which 6 ml of acid mixture (conc. sulphuric acid and conc. orthophosphoric acid) and about 3g of catalyst mixture ( $K_2SO_4$  and Selenium) were added and exposed to about 370 °C in order to allow digestion. Then, distillation took place in (Kjeltec\* 2300 Analyzer unit, FOSS, Sweden) by adding 25 ml of 40% NaOH and using 25 ml of boric acid with 10 drops of indicator solution. Finally, the distillate was titrated with standardized 0.1N sulphuric acid to a reddish color. The crude protein content was estimated using the formula:-

$$\text{Total nitrogen, percent by weight} = \frac{(V_2 - V_1) \times N \times 14.007 \times 100}{W}$$

Where,  $V_2$ =Volume in ml of the standard sulphuric acid solution used in the titration of the test material

$V_1$ = Volume in ml of the standard sulfuric acid used in the titration for the blank determination

N= Normality of the standard sulphuric acid

W= weight in grams of test material

Crude protein content, percent pre weight = total nitrogen × 6.25

### **3.3.1.2 Determination of crude fat**

A clean and dried thimble containing about 5 g of dried sample and covered with fat free cotton at the bottom and top was placed in the extraction chamber. Then, extraction took place using (2055 SOXTEC extraction unit, FOSS extractor, Sweden) for at least 4hrs according to AOAC (2000) official method 4.5.01. The crude fat content was determined by the formula:-

$$\text{Crude fat (\%)} = \frac{M_2 - M_1}{M} \times 100\%$$

M<sub>2</sub>=mass of flask and lipid extracted

M<sub>1</sub>=mass of dried flask

M = weight of sample on dry basis

### **3.3.1.3 Determination of crude fiber**

Crude fiber analysis was conducted using the method of AOAC (2000) official method 962.09. About 1.6g weighed sample was transferred into a 600 ml beaker and about 200 ml 1.25% sulfuric acid was added and boiled for 30 minutes. Recording took place by placing a watch glass over the mouth of the beaker. After 30 minutes heating by gently keeping the level constant with distilled water, 20 ml 28% KOH was added and boiled gently again for another 30 minutes. Subsequently, washing was conducted with 1% sulfuric acid and NaOH solution. After, filtering it was then dried in an electric oven (Mettler 854 Schwabach, West Germany) at 130 °C for 2hrs. Furthermore, it was cooled at room temperature for 30 minutes in a desiccators and weighed, then transferred the crucibles to muffle furnace (Carbolite Aston Lane, Hope,S20

England.) for 30 minute ashing at 550 °C Finally, it was cooled again in desiccators and re-weighed. The crude fiber content was determined by using the formula:-

$$\text{Crude fiber content} \left( \frac{\text{gm}}{100} \right) = \frac{[(w_1 - w_2)(100 - m)]}{w_3}$$

where ,  $w_1$  = crucible weight after drying,  $w_2$  = crucible weight after ashing,  $w_3$  = dry weight

$m$  = % moisture of the sample

### 3.3.1.4 Determination of moisture content

Moisture of the taro flour was determined according to AOAC (2000) using the official method 925.09. A clean dried and covered flat aluminum dishes were weighed and about 5gm of the sample were transferred to the dish. The dish then placed in the oven (Memmert 854 Schwabach, West Germany) at 102 °C for overnight and cooled in desiccators and re-weighed. Then, the moisture content was estimated by the formula:-

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

### 3.3.1.5 Determination of total ash

The porcelain dish used for the analysis was washed by dilute hydrochloric acid on boiling. And it was washed with distilled and de-mineralized water respectively. Then dried at 120<sup>0</sup>C in an oven and ignited at 550<sup>0</sup>C in (Carbolite, Aston Lane, Hope, Sheffield s30 2RR, England) furnace for 3 hour. The dish was then removed from furnace and cooled in desiccators. The mass of the

dish was measured using (ARZ140, N315, SNR=1203290469, USA) analytical balance ( $M_1$ ). About 2.5 gm of sample powder was weighed in to the porcelain dish ( $M_2$ ). The sample was charred at 120<sup>0</sup>C on hot plate (Wagtech, UK, hot plate SH3), until the whole content becomes carbonized. Then the sample was placed in a (Carbolite, Aston Lane, Hope, Sheffield s30 2RR, England) furnace at 550<sup>0</sup>C until whitish color appears. The sample was removed from the furnace and placed in desiccators. Finally the mass was weighed as ( $M_3$ ).

$$\text{Ash (\%)} = \frac{M_3 - M_1}{M_2 - M_1} \times 100\%$$

$M_1$ =mass of the dried dish

$M_2$ =mass of the dish and the sample (on DB)

$M_3$ =mass of the dish and the ash

### **3.3.1.6 Utilizable carbohydrate (CHO) determination**

The total utilizable carbohydrate was calculated by difference with the exclusion of crude fiber.

Total carbohydrate (%) = 100 - (fat + fiber + protein + ash)

### **3.3.1.7 Total energy in kilo calories**

The gross energy (GE) content in each sample was determined mathematically using the following formulae:

Total energy (Kcal) = (9 × crude fat content + 4 × protein content + 4 × CHO Content)

### **3.3.2 Mineral analysis**

Up on ashing for the determination of the total ash content 3 drops of 1M HNO<sub>3</sub> acid was added to the sample in each of the crucible. The ash was digested by using 6N hydrochloric acid. The digested sample was filtered in to sample bottles each using the Whatmann filter paper (42mm) prior to analysis. The Fe, Zn, Mg, Ca, Mn and Cu content in the sample was determined using

atomic absorption Spectrophotometer (AAS) of (Buck Scientific Atomic absorption Spectrophotometer, 210VGP, Canada) at 248.3nm, 213.9nm, 285.2nm, 422.7nm and 279.5nm Wavelengths respectively using air acetylene flame. Na was measured using atomic emission spectroscopy. The concentration of the elements in the sample was calculated as:-

$$\text{Concentration (mg/100g)} = \frac{(a-b) \times V}{10 \times \text{wt. of sample}}$$

Where; a = concentration in ppm of sample solution

b = concentration in ppm of blank solution

V = volume in mL of the extract

#### ➤ **Total phosphorous determination**

The sample solutions prepared for mineral determination were used for phosphorous determination. 1ml of the clear extract (sample solution prepared for mineral determination) was diluted into 50ml with deionized water. Five ml of the sample solution was added into test tube. Half ml of molybdate and 0.20mL aminonaphtholsulphonic acid were added into the test tube (sample solution) and mixed thoroughly step by step. The solution was allowed to stand for 10 minutes.

#### ➤ **Standard curve preparation**

Six series of working standard phosphorous solutions (0.2, 0.4, 0.6, 0.8 1.0 and 1.2 µg/ml) were prepared by appropriate dilution of the phosphorous stock solution (1000 µg P/ml of KH<sub>2</sub>PO<sub>4</sub>) with deionized water using 10ml volumetric flask. The instrument was calibrated to zero using distilled and deionized water. The absorbance of the standard sample, blank and sample solution

were measured at 660 nm using ( BECKMAN, DU-JAPAN) UV-VIS spectrophotometer. Calibration curve (concentration versus absorbance) using the prepared standard solutions was prepared. And the concentration of phosphorus in the sample solution was determined using the following equation:

$$\text{Phosphorous (mg/100g)} = \frac{\text{sample absorbance} - \text{blank absorbance}}{\text{slope} \times \text{wt.sample}} \times \text{Dilution Factor}$$

### **3.3.3 Physicochemical and Functional Properties of Taro Flour**

#### **➤ Physicochemical Properties**

##### **Tuber size determination**

The sizes of the tubers were measured using a calibrated balance by directly placing the tubers on the analytical balance after adjusting the balance to zero.

##### **Determination of pH value**

The pH of the samples was determined according to the method of AOAC (1984). About 10 g of the samples were weighed in triplicates in 250ml beaker and mixed with 50 ml of distilled water and stirred for 10 min. The pH of the sample was determined by dipping the electrode of the Jenway pH meter (Jenway 370 pH meter, Dunmo ESSEX CM6 3LB, England) in the mixture. The pH meter was calibrated using pH 4.0 and 7.0 buffers prior to determination of the pH of the samples.

### **Determination of Titratable Acidity**

Total Titratable acidity expressed as percentage lactic acid was determined by titrating 25 ml of the decanted homogenate samples used for pH determination against 0.1 N NaOH to pH 8.30.

#### **➤ Functional properties**

##### **Emulsion capacity and stability**

Emulsification capacity was determined according to the procedure of Beuchat et al., (1975) at room temperature. About 2 g flour sample and 23 ml of distilled water solution were mixed for 30 s using a Wagtech (Wagtech, SH3 England) magnetic stirrer at 10 Ruhrer speed. After complete dispersion, refined vegetable oil (soybean oil, SUNNY, Egypt, density 0.918g/ml) was added continuously (in ml portions) from a burette and blending continued at room temperature ( $23\pm 1^{\circ}\text{C}$ ) until the emulsion breakpoint was reached, when there was separation into two layers. The emulsion stability was recorded by observing the volume of water which was not emulsified after 24 hours. The values of emulsion capacity were recorded as ml of oil emulsified per g of samples (ml/g) and emulsion stabilities were recorded in ml water which is not emulsified after 24 hours of keeping.

##### **Water and oil absorption**

Water and oil absorptions were determined according to the following procedure. About 1-g dry taro flour sample was weighed in a centrifuge tube and mixed with 15 ml of distilled water or fresh light yellowish soybean oil (soybean oil, SUNNY, Egypt density 0.918 g/ml) at room temperature ( $23^{\circ}\text{C} \pm 1^{\circ}\text{C}$ ) for 15 minutes. The mixture was centrifuged using (DYNAC II centrifuge, Clay Adams, division of Becton and Dickinson Company, USA) at 80rev/min for 45

min and after that water or oil which was not absorbed by the flour was noted and recorded. The values were expressed as milliliters of oil or water absorbed per gram of dry flour.

### **Foaming capacity and stability**

The foam capacity was determined using the method of Coffman and Garcia, (1977) the flour (2 g) was suspended in distilled water (100 ml) and stirred at room temperature for 5 min using a magnetic stirrer at 10 Ruhrer speed (Wagtech,SH3 England). The contents along with the foam were immediately poured into a 250 ml measuring cylinder. Volume of foam (ml) after mixing was expressed as the foam capacity and then volume over a time period of 20-120 min as foam stability for the respective time periods.

### **Bulk density of the flour**

A 50 g flour sample was added into a 100 ml measuring cylinder. The cylinder was tapped continuously until a constant volume was obtained. The bulk density ( $\text{g cm}^{-3}$ ) will be calculated as weight of flour (g) divided by flour volume ( $\text{cm}^3$ ) (Oladele and Aina, 2007).

### **Swelling power and solubility**

Known amount of dry taro flour (mo; ~ 0.5 g) was dispersed in 15 ml of water. The dispersion was heated under mild agitation at 80 °C for 30 minutes. The gelatinized dispersions were then centrifuged at 3000xg using (DYNAC II centrifuge, Clay Adams, division of Becton and Dickinson Company, USA) for 15 minutes. After which, the supernatant was decanted and dried at 100 °C until a constant weight (ms) reached. The swelling power and solubility were calculated using the following equation:

$$\text{Swelling Power [g/g dry flour]} = \frac{m_{sw}}{m_o (1 - \text{solubility})}$$

$$\text{Solubility [g/g dry flour]} = \frac{m_s}{m_o}$$

Where,  $m_{sw}$  is the weight of swollen starch granules,  $m_s$  weight of dried supernatant,  $m_s$  the weight of decanted and dried supernatant,  $m_o$  is weight of flour used.

### **3.3.4 Analysis Methods for some Antinutrients**

#### **3.3.4.1 Phytic acid analysis**

The Phytate content was determined according to method described by Latta and Eskin (1980), and later modified by Vaintraub and Lapteva (1988). About 0.075 grams of dried sample was extracted with 10mL 2.4% HCl for 1 h at ambient temperature and centrifuged at (3000 rpm/ 30 min) using (DYNAC II centrifuge, Clay Adams, division of Becton and Dickinson Company, USA). The clear supernatant was used for the phytate estimation. One milliliter of Wade reagent (0.03% solution of  $\text{FeCl}_3 \cdot 6\text{H}_2\text{O}$  containing 0.3% sulfosalicylic acid in water) was added to 3mL of the sample solution and the mixture was centrifuged. The absorbance at 500nm was measured using UV-VIS spectrophotometer (BECKMAN, Du-64 Japan). The phytate concentration was calculated from the difference between the absorbance of the control (3mL of water+1mL Wade reagent) and that of assayed sample. The concentration of phytate was calculated using phytic acid standard curve and results were expressed as of phytic acids in mg per 100 g dry weight.

To prepare the phytic acid standard curve, a series of standard solution were prepared containing 5–40 mg/ml phytic acid in water (Latta and Eskin, 1980). Three milliliters of the standards were pipetted into 15mL centrifuge tubes with 3mL of water used as a zero level. To each tube was

added 1mL of the wade reagent, and the solution was mixed using a vortex mixer (Maxi mix II M 37610-26 Thrmolyne Dubaque Iowa USA) for 5 s. The mixture was centrifuged for 10 min and the supernatant read at 500nm by using water to zero the spectrophotometer reading. The phytate content in taro was calculated using the following relation:

$$\text{Phytate (mg/100g)} = \frac{(\text{Absorbance} - \text{Intercept})}{(\text{Slope} \times \text{Dencity} \times \text{Wt. Sample}) \times 3}$$

#### **3.3.4.2 Tannins analysis**

Tannins were determined using Butler (1971) as modified by Maxson and Rooney (1972). About 0.25gm of taro flour was weighed in a screw capped test tube and 10ml of 1% HCl in methanol was added to each test tube containing the samples, then the tubes were put on mechanical shaker for 24 hours at room temperature. After 24 hour of shaking, the tubes were centrifuged using (DYNAC II centrifuge, Clay Adams, division of Becton and Dickinson Company, USA) at 1000xG for 5 min. 1ml of the clear supernatant was taken and mixed with 5ml of vanillin-HCl reagent in another test tube, and this mixture was allowed to stand for 20 min to complete the reaction. After 20 min the absorbance was read at 500nm using spectrophotometer (BECHMAN Du-64, Japan).

#### **Preparation of the Standard Curve**

D-Catechin was used as the standard value of tannin in mg D-Catechin/g of sample. 40mg of D-Catechin was weighed and dissolved in 100ml of 1% HCl in methanol. 0, 0.2, 0.4, 0.6, 0.8, 1.0ml of stock solution was pipetted out in a test tube and the volume of each test tubes were adjusted to 1ml using 1% HCl in methanol, then 5ml of vanillin-HCl reagent was added to each tube and

the test tubes were kept for 20 min to complete the reaction finally the absorbance were read at 500nm and the standard curve was constructed using concentration v<sub>s</sub>. series of absorbance.

The concentration of tannin in the taro flour samples were calculated using formula:

$$\text{Tannin( mg/100g)} = \frac{\text{Absorbance} - \text{Intercept}}{\text{slope} \times \text{Density} \times \text{wt.sample}}$$

#### **3.3.4.3 Cyanide analysis**

The amount of cyanide in taro flour was determined following the method of (AOAC, 1995), using official method, 49.49.

20 g of taro flour sample was placed in extraction flask and it was followed by addition of 100 ml distilled water and allowed to stand for two hours, in order to set free all the bound hydrocyanic acid, meanwhile keeping the flask connected with apparatus for distillation. After two hours of maceration 100 ml of distilled water was added to the slurry and steam distilled. The distillate was collected in 20ml of 0.01N AgNO<sub>3</sub> that has been acidified with 1M HNO<sub>3</sub>. The distillation process was allowed to proceed for 40minute with vigorous boiling. After passing over 150ml of the distillate, the distillate was filtered through Gooch with little water and the excess of AgNO<sub>3</sub> was titrated in combined filtrate and washing with 0.02 N KSCN, using ferric alum indicator. The end point of titration was indicated by appearance of faint reddish color up on addition of 0.02 N KSCN solution. The quantity of HCN in the sample was calculated from the relation:

ml of AgNO<sub>3</sub> consumed to complex CN<sup>-</sup> = 20-2V

Where, V= volume of the titer

1ml of 0.01AgNO<sub>3</sub> =0.27 mg HCN

#### **3.3.4.4 Oxalate analysis**

The oxalate contents of both raw and processed taro flours were determined using the method of Iwuoha and Kalu, (1995). This method involves the following three steps: digestion, oxalate precipitation and permanganate titration.

##### **i. Digestion**

At this step about 2g (db) of taro flour was suspended in 190ml of distilled water contained in 250-ml conical (Erlenmeyer) flask; 10ml of 6M HCL was added and the suspension was then digested at 100 °C for 1 hour, this was followed by cooling, and then solution was made up to 250mL before filtration using distilled water .

##### **ii. Oxalate precipitation**

Duplicate portions of 125 ml of the filtrate were measured into a beaker and four drops of methyl red indicator was added, followed by the addition of concentrated NH<sub>4</sub>OH solution (drop wise) until the test solution changed from its salmon pink color to a faint yellow color (pH 4-4.5). 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% CaCl<sub>2</sub>, solution was added while being stirred constantly. After heating, it was cooled and left overnight at 5°C. The solution was then centrifuged at a speed of 2500 rev/min for 5 min. The supernatant was decanted and the precipitate completely dissolved in 10 ml of 20% (v/v) H<sub>2</sub>SO<sub>4</sub> solution.

### iii. Permanganate titration

At this point, the total filtrate resulting from digestion of 2 g of flour was made up to 300 ml. Aliquots of 125 ml of the filtrate were heated until near-boiling, and then titrated against 0.05M standardized  $\text{KMnO}_4$  solution to a faint pink color which persisted for 30 s. The calcium oxalate content was calculated using the formula:

$$\text{oxalates} = \frac{T \times (V_{me})(DF) \times 105}{(ME) \times m_f} \text{ (mg/100g)}$$

where  $T$  is the titre of  $\text{KMnO}_4$ , (ml),  $V_{me}$  is the volume -mass equivalent (i.e. 1  $\text{cm}^3$  of 0.05 M  $\text{KMnO}_4$  solution is equivalent to 0.00225 g anhydrous oxalic acid),  $DF$  is the dilution factor  $V_T A$  (2.4, where  $V_T$  is the total volume of filtrate (300ml) and  $A$  is the aliquot used (125 ml)),  $ME$  is the molar equivalent of  $\text{KMnO}_4$  in oxalate ( $\text{KMnO}_4$  redox reaction. (5)) and  $m_f$  is the mass of flour used.

## 3.4 Focused Group Discussion

Focused group discussions were conducted with different groups of people in Boloso Sore worda. The groups includes; farmers, researchers, consumers and retailers of taro in the local market. The farmers group contained 5 members, the retailers group was composed of 3 female and 1 male and there was 2 senior researchers 2 food science and post harvest technologists and one trained farmer who work as assistance researcher, in the researchers group.

## 3.5 Statistical analysis and data processing

One-way analysis of variance (ANOVA) was conducted on each of cultivars and Least Significant Difference (LSD) test at significant level of  $p < 0.05$  was performed using SPSS

version 15 software for windows to compare the difference between treatment means. The results were expressed as means  $\pm$  standard deviation of three separate determinations.

Pearson bivariate correlation was used at significant level of  $p < 0.01$  using SPSS version 15, to see whether there is correlation between two parameters of interest.

## 4. RESULTS AND DISCUSSIONS

In this chapter the outcome of, focused group discussion, proximate composition, mineral composition, functional properties, the physicochemical properties and the levels of antinutritional factors of the raw and processed taro flours are discussed. Table 4.1, 4.2, 4.3, 4.4, and 4.5, show the results of proximate composition, the mineral composition, functional properties, physicochemical properties and the levels of antinutritional factors for raw and processed samples respectively. All results except moisture content are reported on dry weight basis.

### 4.1 Outcome of Focused Group Discussion

From focused group discussion of the group of the researchers, it was understood that, only one variety of taro namely; *colocasia esculenta* (L.) Schott var. *esculenta* is found in the area. However, one improved, "Boloso I" and a number of taro cultivars with distinct morphological characteristics such as, Gerezua, Shishia, Yitria, Molia, Tawayia, Gesa, Woydua and Kewo Boina are grown in the area.

According to the results of focused group discussion conducted at AARC and with inhabitants of the Boloso Sore woreda of wollaita zone, growing of taro ("GODERE") has the following advantages over other crops especially of root and tuber crops: Higher yield of taro could be obtained from small plot of land (some cultivars are highly productive up to 70 tons per hectare, after harvest taro can be stored longer as compared to other root crops, it is highly appreciated by the consumers because of attractive taste and post harvest quality, has high market price up to 150 Birr per quintal, it is good for children, it is important during drought seasons. , The FGD

also showed that until recently taro corms and cormels are the only edible part of the taro plant in the area. But now the foods science division of AARC has been introducing the consumption of taro leaves in wollaita zone. It was also learned that boiling taro was reported to be the only processing practiced in the area before consumption. After boiling there are two forms of consumption. One is boiling and eating similar to potatoes and the other is; boiling, crushing and making into ball-shaped pieces of mouthful sizes and eating with “Datta” (a local sauce made of spices, hot pepper and butter).

A number of agronomic researches have been conducted in the research center. These includes; indigenous production methods, collection, characterization of taro germplasm growing in SNNPR, agronomic studies like; planting date, spacing on the yield of taro, farmers methods of classification with respect to genetic variability and determination of fertilizer requirement of taro.

Taro grown in the area is relatively tolerant to most pests. But some cultivars are seriously attacked by taro leaf blight disease which is caused by *phythoptora colocasiae*. Farmers also said that rodents attack taro corms while it is in the ground.

Taro in the region is cultivated without application of synthetic fertilizers. Only Manure and house solid wastes are reported to be used as a fertilizer. Therefore taro produced in that particular area can be considered as an organic product, which is currently getting a growing demand all over the world.

## 4.2 Proximate Compositions

The proximate composition of raw “Boloso I” is shown in Table 4.1; Raw Boloso (RB) had protein content of 6.44%, crude fat 0.47%, crude fiber 2.62%, ash 4.82%, moisture 0.544%, utilizable carbohydrate 85.65%, and gross energy 372.56 Kcal/100g DM. The proximate composition of Acc.236000 was: protein 7.85%, fat 0.654%, fiber 2.42%, ash 4.62%, moisture 0.92% total CHO 84.46%, and gross energy of 375.11 K cal/100g DM. The proximate compositions of boiled taro flours are also indicated in table 4.1. Boiled taro contained protein of 5.83%, crude fat 0.87%, crude fiber 3.21%, moisture content of 10.19% total CHO 85.62% and gross energy 373.69 Kcal/100g DM. Flour which was derived from boiled Acc.236000 had protein content of 7.77% 1.05% fat, 3.38% fiber, 4.92% ash, 9.69% moisture content 82.88% total CHO, and gross energy of 372.00Kcal/100DM.

protein content of 9.14%, crude fat 0.35%, crude fiber, 2.21% ash 4.65% moisture content 6.71% total CHO 83.66 % and gross energy 374.32Kcal/100g.

Analysis of variance, (ANOVA) conducted on the moisture contents of raw taro had shown that the moisture content of BR (0.544%) was significantly different ( $P < 0.05$ ) from MC of AR (0.92%).The moisture content of fresh taro corms were also determined and a significant difference ( $p < 0.05$ ) was observed between the moisture content of Boloso I (70.94%) and Acc.236000 with MC of (72.51%). The moisture content of flours obtained from boiled taro cultivars had shown significant difference ( $p < 0.05$ ) between them. But flours from fermented taro did not show a significant different in their MC.

**Table 4.1 proximate composition of raw and processed taro**

Sample Type	Protein*(%)	Fat (%)	Fiber (%)	Ash (%)	Moisture (%) <sup>♦</sup>	Utilizable Carbohydrate (%)	Gross Energy (Kcal/100 g DM)
BR <sup>†</sup>	6.43 ±0.01 <sup>d</sup>	0.47 ±0.08 <sup>a</sup>	2.63 ±0.05 <sup>a</sup>	4.82 ±0.04 <sup>a</sup>	0.54 ±0.03 (70.9) <sup>a</sup>	85.65 ±0.07 <sup>a</sup>	372.55 ±0.41 <sup>a</sup>
AR	7.85 ±0.02 <sup>b</sup>	0.65 ±0.11 <sup>b</sup>	2.42 ±0.06 <sup>b</sup>	4.62 ±0.01 <sup>a</sup>	0.91 ±0.01 (72.5) <sup>b</sup>	84.46 ±0.18 <sup>b</sup>	375.11 ±0.30 <sup>b</sup>
BB	5.83 ±0.06 <sup>c</sup>	0.87 ±0.04 <sup>c</sup>	3.21 ±0.01 <sup>c</sup>	4.46 ±0.22 <sup>a</sup>	10.19 ±0.02 <sup>c</sup>	85.63 ±0.28 <sup>a</sup>	373.68 ±0.62 <sup>c</sup>
AB	7.77 ±0.01 <sup>b</sup>	1.05 ±0.16 <sup>d</sup>	3.38 ±0.04 <sup>d</sup>	4.92 ±0.47 <sup>a</sup>	9.69 ±0.0002 <sup>d</sup>	82.88 ±0.27 <sup>c</sup>	372.00 ±2.51 <sup>a</sup>
BF	6.98 ±0.00 <sup>c</sup>	0.41 ±0.001 <sup>ca</sup>	2.46 ±0.002 <sup>b</sup>	5.44 ±0.11 <sup>b</sup>	6.05 ±0.004 <sup>e</sup>	84.74 ±0.10 <sup>b</sup>	370.46 ±0.49 <sup>d</sup>
AF	9.14 ±0.30 <sup>a</sup>	0.35 ±0.09 <sup>ea</sup>	2.21 ±0.06 <sup>c</sup>	4.65 ±0.36 <sup>a</sup>	6.71 ±0.002 <sup>f</sup>	83.66 ±0.56 <sup>d</sup>	374.32 ±1.94 <sup>c</sup>

\* Values are means of triplicates analysis ± standard deviations

<sup>a-f</sup> values with different superscripts in the same columns are significantly different at P<0.05

<sup>†</sup>BR, Boloso I Raw, AR, Acc.236000 Raw, BB, Boloso Boiled, AB, Acc.236000 Boiled, BF, Boloso I Fermented, AF, Acc.236000 Fermented

<sup>♦</sup>Values in bracket for moisture content is the moisture content of fresh taro tubers.

The low MC observed for raw taro flours was due to the drying of the fresh tubers using freeze drier. The range of MC (70.94-72.51%) obtained for fresh taro corms was within the range of MC which were reported by Nip, *et al.*, (1989), and Huang *et al.*, (2007) and slightly higher than the values reported by EHNRI, (1997). The MCs of raw taro flours were also within the range of freeze dried taro flours obtained from six cultivars of taro grown in American Samoa (Nip, *et al.*, (1989). The high MC of fresh taro corms may be one limitation of production and utilization of taro. Therefore, there should be an effective processing method like converting to flours with a lower MC. This may reduce the high post harvest losses imposed due to its MC.

As shown in Table 4.1, the protein content of raw “Bolosio I” is significantly different ( $p < 0.05$ ) from the protein content of Acc.236000. There is also a significance difference between protein content of boiled samples of both cultivars at similar p-value. A similar difference ( $p < 0.05$ ) was also observed between the protein content of flours from fermented taros of both cultivars. The protein content of RB is significantly different ( $p < 0.05$ ) from of its boiled. But no significant difference ( $p > 0.05$ ) was observed between the protein contents of boiled and raw samples of Acc.236000.

A decrease in protein content of taro was recorded due to boiling, accordingly the protein content of Bolosio I decreased by 9.37% and Acc.236000 by only 1.00%. Whereas the protein content of taro flours had resulted in a significant increase due to fermentation. Fermented taro had shown an increase in protein content by 8.46% and 16.5% for Bolosio I and Acc.236000, respectively. The observed increase in protein content of fermented taro flours could be due to synthesis of amino acids during the fermentation process (Obloh, and Elusiyan, , 2007). And the reason for the observed decrease in protein content by the boiling process could be due to the denaturaton of protein and the leaching out of soluble amino acids in the coking medium (FAO, 1990).

The range of protein contents 6.44% -7.85% were fall within the protein content of taro as described by (Serge Treche 1996), but it was higher than the values reported by Mbofung *et al.*, (2006).

The crude fat content of BR (0.47%) was shown to be significantly different ( $p < 0.05$ ) from the crude fat content of AR (0.65%). Similarly, ANOVA had shown that fat content of the RB was significantly different ( $p < 0.05$ ) from the fat content of and AF and BF.

The crude fat content of taro cultivars used in this study was higher than the range of fat contents which were reported by Mbofung, *et al.*, (2006), for five cultivars of taro grown in Cameroon and Chad, and for five cultivars of taro grown in American Samoa (Nip, *et al.*, 1989).

Except BF and AF, analysis of variance did not show significant difference ( $p > 0.05$ ) in total ash content among the samples.

The range of the total ash content of taro flours from both cultivars studied (4.46-5.44%) were higher than the ash contents of taro that were reported by Nip, *et al.*, (1989), and Huang, *et al.*, (2007), the ash contents of *Tannia (Xanthosoma species)*, reported by Akpan and Umoh, (2004) and by Nijoku and Ohia, (2007). However the current results were lower than the ash content of taro reported by Njoku and Ohia, (2007).

The observed difference in the ash contents may be attributed to climatic factor, the soil type, and the varietal and/or cultivar difference. From the high ash contents of the taro samples studied one can easily understand that there would be appreciable quantity of minerals in taro.

Analysis of variance conducted on fiber content of the sample showed that the fiber content of raw samples both cultivars of taro are significantly different ( $p < 0.05$ ) with each other and with their respective fermented samples.

The range of crude fiber contents (2.63-2.42), were lower than the values previously reported by Nip, *et al.*, (1989), but it was higher than the crude fiber content reported by Jirrarat, *et al.*, (2007) for taro cultivars of Thailand. The values observed in the present study also fall within the range of crude fiber content of five cultivars of taro grown in Cameroon and Chad (Mbofung, *et al.*, 2006).

The fiber content of the boiled samples was increased by 21.95% and 39.84% for Bolos I and Acc.236000 respectively from raw samples. Whereas fermentation of both cultivars has resulted in decrease of fiber by 6.44% and 6.74% for Boloso I and Acc.236000 respectively. No explanation was obtained for the observed increment of fiber content due to boiling process. The possible reason for observed decrease in fiber content the present study could be the enzymatic degradation of the crude fiber by the enzymes excreted by the microorganisms involved in the fermentation process.

From the results of the current study it can be observed that taro is a very good source of carbohydrate (CHO). The CHO of BR was significantly different ( $p < 0.05$ ) from the CHO of AR. However, there was no that no significant difference ( $p > 0.05$ ) between the CHO content of raw taro and boiled taro samples in both cultivars. On the other hand the CHO of fermented taro flours from both cultivars had shown significant difference ( $p < 0.05$ ) from their respective raw form. The range of vales obtained for CHO in this study (83.66-85.65) ,were lower than the values reported for six cultivars of taro grown in American Samoa, (Nip *et al.*, (1989). The reason for the observed differences in CHO content of samples in the present study from earlier works could be attributed to, the cultivar difference, the climate, the type of soils and others.

The range of values obtained for gross energy (GE) (370.46-375.11Kcal/100g) were very comparable to the GE of maize and higher than GE of cassava, Irish potato, yam, sweet potato and taro (Serge Treche, 1996) and less than the GE of rice and sorghum as reported by the same author. This quantity of energy makes taro one of the most carbohydrate rich food in supplying high quantity energy per a given mass of a food consumed.

### **4.3 Mineral Composition of Taro**

Eight different kinds of minerals were analyzed for their concentration in dry weight basis. Except sodium (Na) all minerals were analyzed using atomic absorption spectroscopy (AAS), but Na was determined using atomic emission spectroscopy (AES). Due to the less reliability of atomic emission spectroscopy for potassium metal at chemistry department of AAU, the potassium (K) content in taro was not determined. Table (4.2) shows the mineral composition of raw, boiled and fermented taro flours.

Sample of Boloso I had, Fe (5.86mg/100g), Zn (43.08mg/100g), Ca (45.23mg/100g), Na (13.81mg/100g), Mg (7.24mg/100g), Cu (0.433mg/100g), Mn (3.61mg/100g) and P (7.77mg/100g) (Table 4.2). Raw sample from cultivar Acc.236000 also contained all the minerals that are found in cultivar Boloso I, accordingly it contained Fe (6.08mg/100g), Zn(48.16mg), Ca (31.81mg/100g), Na (14.58mg/100g), Mg (7.32mg/100g), Cu (0.46mg/100g), Mn (1.27mg/100g) and P (13.50mg/100g).

There was no significant difference ( $P > 0.05$ ) existed in the contents of minerals Fe, Mg, and Cu between the raw samples of both cultivars (Table 4.2). But a significant difference was observed in the contents of Mn, Zn, Ca, Na and P of the raw samples of the two cultivars. Similarly no

significant difference ( $P > 0.05$ ) was observed between the contents of Fe, Na, Mg, Cu, for the boiled taro cultivars studied. Significant difference was ( $p \leq 0.05$ ) observed between fermented taro samples in their Fe, Zn, Ca, Na, Mg and Mn, content. But the P and Cu content of fermented taro did not show significant difference at similar p-value.

The range of values obtained for iron (5.85-6.08) for raw taro samples of both cultivars were less than the value which were reported by Nijoku and Ohia, (2007).

The range of values for Mg, Na, P, and Cu are less than the values previously reported by Nijoku and Ohia, (2007), and Huang *et al.*, (2007). But the range values for Zn (43.98-48.16) were higher than the values reported by the same authors. The calcium content of taro cultivars was within the range of the values reported by Huang *et al.*, (2007), however these values were less than the values reported by Nijoku and Ohia, (2007), and Mbofung, *et al.*, (2006).

Among the minerals analyzed in this study the composition of Cu is the least. The low composition of taro in Cu is one good advantage since Cu is essential mineral for normal body function in very small quantity.

Compared to other works conducted on the mineral composition of taro the two Ethiopian cultivars of taro contained high concentration of zinc. This could be a very good finding since there is a high Zn prevalence in Ethiopia and in East Africa in general (Umata *et al.*, 2005).

Boiled samples of both cultivars had shown an increase in their calcium content. The reason for the observed increments could be due to the tap water used for boiling process.

**Table 4.2. Mineral composition of raw and processed taro flours**

Minerals	Sample Type <sup>†</sup>					
	BR*	AR	BB	AB	BF	AF
<b>Fe<sup>y</sup></b>	5.86 ±0.7471 <sup>a</sup>	6.08 ±0.09 <sup>a</sup>	6.03 ±0.02 <sup>a</sup>	5.59 ±0.19 <sup>a</sup>	4.13 ±0.04 <sup>b</sup>	4.87 ±0.02 <sup>c</sup>
<b>Zn</b>	43.08 ±0.20 <sup>a</sup>	48.16 ±0.12 <sup>b</sup>	14.77 ±0.16 <sup>c</sup>	26.99 ±0.13 <sup>d</sup>	11.65 ±0.06 <sup>c</sup>	13.76±0.12 <sup>f</sup>
<b>Ca</b>	45.23 ±2.11 <sup>a</sup>	31.81 ±0.08 <sup>b</sup>	47.49 ±0.55 <sup>c</sup>	36.74 ±1.40 <sup>d</sup>	42.99 ±0.05 <sup>e</sup>	30.96 ±0.07 <sup>b</sup>
<b>Na</b>	13.81 ±0.10 <sup>a</sup>	14.58 ±0.57 <sup>b</sup>	15.74 ±0.59 <sup>c</sup>	15.54 ±0.001 <sup>c</sup>	12.29 ±0.04 <sup>d</sup>	13.30 ±0.19 <sup>a</sup>
<b>Mg</b>	7.24 ±0.03 <sup>a</sup>	7.32 ±0.21 <sup>a</sup>	8.23 ±0.05 <sup>b</sup>	8.11 ±0.01 <sup>b</sup>	8.94 ±0.01 <sup>c</sup>	8.04 ±0.05 <sup>d,b</sup>
<b>Cu</b>	0.43 ±0.04 <sup>a</sup>	0.46 ±0.02 <sup>a</sup>	0.59 ±0.10 <sup>b</sup>	0.5645 ±0.001 <sup>b</sup>	0.43 ±0.03 <sup>a</sup>	0.45 ±0.01 <sup>a</sup>
<b>Mn</b>	3.61 ±0.17 <sup>a</sup>	1.27 ±0.01 <sup>b</sup>	1.52 ±0.07 <sup>b</sup>	5.32 ±0.25 <sup>c</sup>	3.99 ±0.02 <sup>d</sup>	1.35±0.03 <sup>b</sup>
<b>P</b>	7.77±0.71 <sup>a</sup>	13.50±0.60 <sup>b</sup>	11.09±1.82 <sup>c</sup>	17.39±2.55 <sup>d</sup>	15.54±0.33 <sup>b, d</sup>	17.77±0.09 <sup>d</sup>

\*All values are means of triplicate analysis ±standard deviation

<sup>a-c</sup> Values which are followed by different letters of superscripts in the same row are significantly different

<sup>†</sup>BR, Boloso I Raw, AR, Acc.236000 Raw, BB, Boloso Boiled, AB, Acc.236000 Boiled, BF, Boloso I Fermented, AF, Acc.236000 Fermented

<sup>y</sup> Values are expressed in( mg/100g) of dry weight basis

But very small amount of reduction in calcium content of taro as a result of fermentation.

According to FAO (1990) the low level and the variations in the composition of some minerals determined in this study from others obtained in previous literatures could be attributed to many factors. As with all crops the nutritional composition of root and tuber crops varies from place to place depending on the climate, the soil, the crop variety (cultivar) and others.

Nijoku and Ohia, (2007), suggested that the samples analyzed for mineral composition can be contaminated by materials used for ashing as well as the lining of the furnace. Dissolved ions used for sample preparation can also influence the results obtained. Agricultural activities, waste disposal, methods of analysis and error in calculation may also play significant role in varying the results.

#### **4.4 Functional properties**

Functional properties of both raw and processed taro flours obtained from the two cultivars used in this study were determined. Table (4.3) shows the values of the different functional properties.

The bulk density (BD) of flour from raw boloso I is 0.80g/ml which is not significantly different from the raw flour of Acc.236000 ( $p < 0.05$ ). Similarly no significant difference observed between the BD of flours which were obtained from boiled samples of both cultivars, but BD of flours from fermented taro of both cultivars had shown significance difference ( $p < 0.05$ ) between them. Flour from boiled Acc.236000 cultivar had the highest BD (0.88g/ml) and flour from fermentation of the same cultivar had the least BD (0.70g/ml). Fermentation of raw flours of both cultivars resulted in a decrease of BD by 10.73% and 13.66% for Boloso I and

Acc.236000 respectively. This is one good advantage in decreasing the cost of packaging if the product is going to be packed.

Water absorption capacity (WAC) of flour from Boloso I was 2.38ml/g which was significantly different ( $p < 0.05$ ) from the flour of Acc.236000 (2.75 ml/g). But no significance difference ( $p < 0.05$ ) in WAC of Boiled Acc.23600 had shown the highest WAC of 3.82ml/g which was followed by flour from boiled boloso I. The highest increase of WAC of boiled taro flours may be due to the gelatinization of the starch molecules {Reference}.

The ability to absorb water is a very important property of all kinds of flours used in the food preparation (Mbofung *et al.*, 2006). The range of WAC (2.38-2.75 ml/100g) of raw taro flour obtained in this study fall within the range of WAC that were reported by Mbofung *et al.*, (2006), but flours from boiled taros of both cultivars studies have higher WAC (3.65-3.82) than flours that were reported by the same author.

The ability to absorb water is sometimes attributed to its protein content. However, the results obtained in this study indicate that no significant correlation ( $p < 0.05$ ) existed between protein content of taro flours and their WAC. Moreover this also supported by the lower WAC of fermented taro flours with the highest protein content and the highest WAC with the lowest protein content obtained in this study.

Flour from fermentation of Acc.236000 had registered the highest OAC, (1.63ml/g) and flour from boiled taro of the same cultivar, (0.9ml/g). No significant difference in OAC was observed for flours from BR, AR and BB at  $p < 0.05$ . Similarly OAC of AB and BR were not significantly different at  $p < 0.05$ . It was also observed that the OAC of flours from fermentation of raw taro flour were not significantly different. Fermentation of raw taro flour had resulted in an increase of the OACs by 45.5% and 25% for Boloso and Acc.236000, respectively.

The values of OAC raw and processed flours in this study (0.9-1.63ml/g) was found to be lower than the values reported by Tagodoe, and Nip, (1994) and Mbofung *et al.*, (2006).

All flour samples were significantly different ( $p < 0.05$ ) with each other in their foaming capacity (FC). The FC of flour from the fermentation of Acc.236000 was the highest (16.05ml); on the other hand boiled boloso flour (BB) had the least FC of (3.45ml). The FC of raw flours from both cultivars was significantly different ( $p < 0.05$ ) from their respective fermented form. Boiling of both cultivars of taro resulted in decrease of FC by 68.81% and 70.95% for Boloso I and Acc.236000, respectively (Table 4.3). But fermentation on the other hand resulted in an increase of FC by 21.1% and 8.45% for Boloso I and Acc.236000 respectively. The increase and decrease of the FC is due to the increase and decrease of the protein content due to the processing. This could be supported by the significant correlation that exists between the protein content of the flours and FC ( $R=0.592$ ,  $p < 0.01$ ).

FCs values observed for raw taro flours (10.9ml/ml-14.8ml/100ml) were within the ranges of foaming capacities of taro flours reported by Njintang *et al.*, (2007) and FC values of flour from fermented Boloso I also within this range, but flour from fermented Acc.236000 had a higher FC than flours reported by the same author. On the other hand boiled taro flours have shown a much lower FC than flours reported by the same author.

According to Tagodoe and Nip, (1994), the foaming capacity of taro flours could be due to its mucilage (a soluble glycoprotein) content and it is negatively affected by heating. That is why boiled taro flours shown the lowest FC. Odoemelam, (2005) also suggested that the reduced foaming capacities could be explained on the basis of native protein denaturaton during heat treatment.

**Table 4.3 Functional properties of raw and processed taro flours**

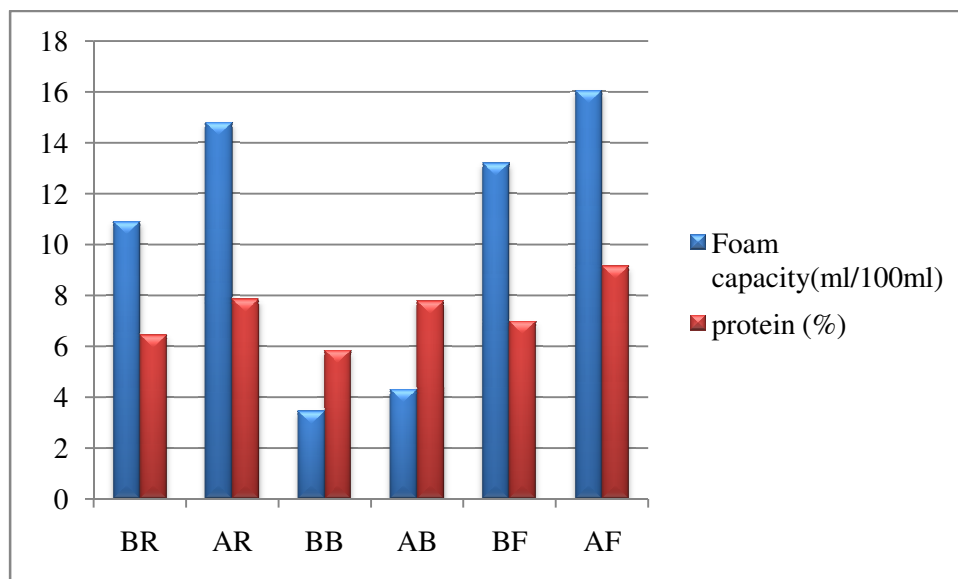
Properties	Sample Type <sup>†</sup>					
	BR*	AR	BB	AB	BF	AF
BD(g/ml)	0.80 ±0.003 <sup>a</sup>	0.81 ±0.003 <sup>a</sup>	0.86 ±0.01 <sup>b</sup>	0.88 ±0.02 <sup>b</sup>	0.73 ±0.00 <sup>d</sup>	0.70 ±0.001 <sup>c</sup>
WAC (ml/g)	2.3750 ±0.13 <sup>a</sup>	2.75 ±0.25 <sup>b</sup>	3.65 ±0.05 <sup>c</sup>	3.82 ±0.16 <sup>c</sup>	1.99 ±0.01 <sup>d</sup>	1.85 ±0.15 <sup>d</sup>
OAC(ml/g)	1.10±0.10 <sup>a,c</sup>	1.30 ±0.20 <sup>a</sup>	1.12 ±0.08 <sup>a</sup>	0.90 ±0.10 <sup>c</sup>	1.60 ±0.10 <sup>d</sup>	1.63 ±0.03 <sup>d</sup>
EC(ml/g)	32.15 ±0.35 <sup>a</sup>	35.65 ±0.35 <sup>b</sup>	10.60 ±0.60 <sup>c</sup>	13.20 ±0.60 <sup>d</sup>	34.20 ±0.30 <sup>c</sup>	36.45±0.35 <sup>f</sup>
ES(ml/g)	9.25 ±0.25 <sup>a</sup>	7.40 ±0.40 <sup>b</sup>	12.90 ±0.10 <sup>c</sup>	12.50 ±0.50 <sup>c</sup>	9.65 ±0.35 <sup>a</sup>	7.75 ±0.25 <sup>b</sup>
FC(ml)	10.90 ±0.90 <sup>a</sup>	14.80 ±0.20 <sup>b</sup>	3.45 ±0.25 <sup>c</sup>	4.30 ±0.20 <sup>d</sup>	13.20 ±0.40 <sup>e</sup>	16.05 ±0.25 <sup>f</sup>
FS(ml)	4.26 ±0.27 <sup>a</sup>	7.40 ±0.30 <sup>b</sup>	1.50 ±0.30	2.35 ±0.15 <sup>d</sup>	5.15 ±0.15 <sup>e</sup>	7.11 ±0.09 <sup>a</sup>
SP(g/g)	8.13 ±0.24 <sup>a</sup>	9.11 ±0.06 <sup>b</sup>	9.04 ±0.04 <sup>b</sup>	9.75 ±0.39 <sup>c</sup>	9.44 ±0.12 <sup>b,c</sup>	6.67±0.62 <sup>d</sup>
S(g/g)	0.16 ±0.002 <sup>a</sup>	0.23 ±0.02 <sup>b</sup>	0.092 ±0.002 <sup>c</sup>	0.12 ±0.03 <sup>d</sup>	0.18 ±0.004 <sup>a</sup>	0.23 ±0.003 <sup>b</sup>

\*values are means of triplicate analysis ±standard deviation

<sup>a-f</sup> Values in the same row with different superscripts are significantly different (p<0.05 )

<sup>†</sup>BR, “Boloso I” Raw, AR, Acc.236000 Raw, BB, Boloso Boiled, AB, Acc.236000 Boiled, BF, Boloso I Fermented, AF, Acc.236000Fermented

Moreover, the linear positive correlation ( $R=0.59$ ,  $p<0.01$ ) observed between FC and protein contents of taro flour in this study could support this observation. Fig. 4.4 shows the relation between FC and protein content.



**Fig. 4.1 Relation between foaming capacity and protein content of different taro flours**

Flour from AR had shown the highest foaming stability (7.4ml) and BB had shown the least FS of (1.5ml). ANOVA performed on the FSs of taro flours had shown that except AR and AF all flours have a significance difference in their stability of foams (Table 4.3). Stable foams are known to occur when lower surface tension and higher viscosity occur at the interface, forming continuous cohesive film around the air vacuoles in the foam. Soluble protein in general play an important role in the formation of foam and this may justify the high foaming capacity of legumes.

The swelling power (SP) of AB (9.75g/g of flour) was the highest of all flours while the fermented flour of the same cultivar had the least SP of (6.67g/g). No significant difference ( $p>0.05$ ) in SP between flours of AR and BB, AB and BF was observed. Both boiling and

fermentation had resulted in an increase of SP of flour from cultivar Boloso I by 11.2% and 16.16% respectively.

The range of values for Swelling Power (SP) of raw and processed taro flours (6.67-9.74g/g) were lower than (SP) flours reported by Jrrarat, *et al.*, (2006), they had reported the SP of taro flour in the range (10.99-16.02g/g). The observed difference may be due to the type of flours used for the analysis. Jrrarat *et al.*, (2006), used purified taro flour (PTF), which have been purified by water and alkaline treatments for their analysis.

Flour from cultivar Acc.236000 was the highest in solubility with a solubility of (0.23g/g of flour) and the flour from boiled sample of boloso I was the least soluble flour having solubility of (0.09g/g). The solubility of flour from RB was significantly different ( $p < 0.05$ ) from all flour samples except is fermented flour. Similarly, ANOVA showed that significance difference ( $p < 0.05$ ) was existed in the solubility of boiled flour from Acc.236000 and the rest of flours. But no significant difference was shown between the solubility of flours of AR and AF at similar p-value. The solubility of raw and processed taro flours (0.092-0.23g/g) was higher than the values reported for taro flours by Jrrarat, *et al.*, (2006).

#### **4.5 Physicochemical properties**

The physicochemical properties of raw and processed taro flours are presented in Table (4.4).

The tuber size of both cultivars was determined and boloso I had the highest tuber size than Acc.236000. Accordingly, average tuber size of Boloso I (119-1563g) and that of Acc.236000 was (527-96g). ANOVA conducted on pH value of the raw and processed taro flours had shown

that all the flours are significantly different with each other ( $p < 0.05$ ). Raw taro flour had pH of 6.26 and 6.44 for Boloso I and Acc.236000 respectively.

Fermentation of raw taro flours had resulted a significant decrease in pH of flours from both taro cultivars. Accordingly the reduction in pH by 21.36% and 19.66% were registered for Boloso I and Acc.236000 respectively.

The ANOVA conducted on TTA of raw and processed taro flours had shown that the values are significantly different ( $p < 0.05$ ). The TTA of raw Boloso I (0.6415%) flour was significantly ( $p < 0.05$ ) higher than the raw Acc.23600 taro flour (0.32%) (Table 4.4). The Titratable acidity of boiled taro flours (0.32%) and (0.35%) for Boloso I and Acc.236000, respectively were lower than that of raw taro flour. On the other hand the TTA of fermented taro flours had the highest of all taro flours.

The observed increment on the TTA of fermented taro flour by 59.2% and 62.69% for Boloso and Acc.236000, respectively, could be the production of organic acid most probably lactic acid by microorganisms, which were involved in the fermentation process. And the observed reduction in TTA of boiled taro flours could be attributed to the leaching out of some oxalic acid that was present in raw boiled taro flour into the boiling water.

**Table 4.4 Physicochemical properties of taro flours**

Properties	Sample Type†					
	BR	AR	BB	AB	BF	AF
pH	6.26 ±0.01 <sup>a</sup>	6.44 ±0.03 <sup>b</sup>	6.32 ±0.01 <sup>c</sup>	6.37 ±0.03 <sup>d</sup>	4.92 ±0.04 <sup>e</sup>	5.17 ±0.04 <sup>f</sup>
TTA(%)	0.5727 ±0.02 <sup>a</sup>	0.64 ±0.01 <sup>b</sup>	0.32 ±0.01 <sup>c</sup>	0.35 ±0.01 <sup>d</sup>	1.40 ±0.02 <sup>e</sup>	1.72 ±.012 <sup>f</sup>
Tuber size(g)	119-1563	96-527	X	X	X	X

<sup>a-f</sup> values with similar superscripts in the same row are not significantly different at p > 0.05

†BR, Boloso I Raw, AR, Acc.236000 Raw, BB, Boloso Boiled, AB, Acc.236000 Boiled, BF, Boloso I Fermented, AF, Acc.236000 Fermented

Except the tuber size the values are means of triplicate analysis ± standard deviation

## 4.6 Antinutritional Factors

Significant quantities of antinutritional factors namely; phytate, oxalate and tannin were found in both raw and processed taro flours Table 4.5. But cyanide was not observed in any of the cultivars.

**Table 4.5 Levels of antinutritional factors of raw and processed taro flours**

Sample Type†	Phytate (mg/100g)	Oxalate (mg/100g)	Tannin (mg/100g)	Cyanide (mg/100g)
BR	115.43 ±2.22 <sup>a</sup>	243.06 ±2.74 <sup>a</sup>	47.69 ±2.06 <sup>a</sup>	ND
AR	135.28 ±0.24 <sup>b</sup>	265.88 ±4.43 <sup>b</sup>	59.9166 ±0.00 <sup>b</sup>	ND
BB	97.79 ±5.03 <sup>c</sup>	72.43 ±0.82 <sup>c</sup>	44.50 ±5.13 <sup>a</sup>	ND
AB	115.08 ±1.18 <sup>a</sup>	70.72 ±1.18 <sup>c</sup>	36.79 ±0.83 <sup>c</sup>	ND
BF	17.60 ±0.34 <sup>d</sup>	159.42 ±1.80 <sup>d</sup>	26.94 ±0.80 <sup>d</sup>	ND
AF	18.03 ±0.03 <sup>d</sup>	170.72 ±2.84 <sup>c</sup>	31.64 ±1.5 <sup>e</sup>	ND

<sup>a-c</sup> means with different superscripts within the same column are significantly different at  $p < 0.05$

ND-Not Detected

†BR, Boloso I Raw, AR, Acc.236000 Raw, BB, Boloso Boiled, AB, Acc.236000 Boiled, BF, Boloso I Fermented, AF, Acc.236000 Fermented

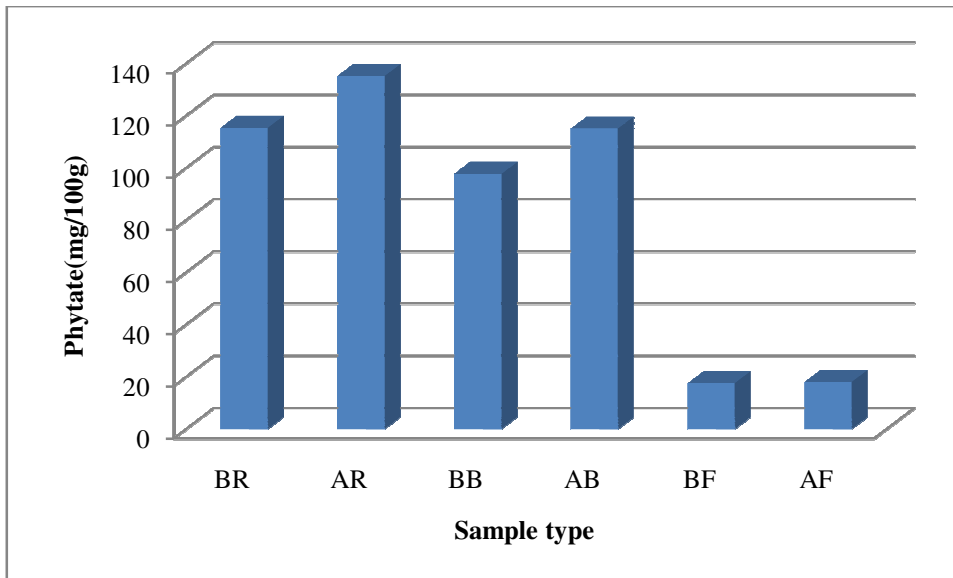
Raw Acc.236000 had the phytate content of 135.28mg/100g of DM which is significantly different ( $p < 0.05$ ) from raw Boloso I (115.43mg/100g DM). The phytate content of flours from boiled taro cultivars also show significant difference between them ( $p < 0.05$ ).

The mean phytate content of raw Boloso I, 115.43mg/100g was significantly different ( $p < 0.05$ ) from the mean phytate (135.27mg/100g) content of raw Acc.236000. ANOVA conducted on the phytate content of taro flours also showed that the mean phytate content of boiled taro flours are significantly different ( $p < 0.05$ ). But no significant difference in the mean phytate content of fermented taro flour at a similar p-value was observed.

Boiled taro had resulted in a decrease of phytate content from the raw flours (Table 4.5). Accordingly, boiling of Boloso I resulted in 15.27 % reduction and Acc.236000 registered a little lower reduction 14.93% from their respective raw form. A higher reduction (about 20%) was observed by Bhandari, Kawabata, (2006) for wild cultivars of yam upon boiling. Bhandari and Kawabata, (2006) suggested that the noticeable decrease in phytate content during boiling may be partly due to either to the formation of insoluble complexes between phytate and other components, such as phytate-protein, phytate-protein-mineral or to the inositol to hexaphosphate hydrolyzed to penta- and tetra-phosphates.

The range of Phytate concentrations observed in unprocessed taro cultivars in this study (115.43-135.28mg/100g) were far below the values reported by FAO, (1990). However these values were comparable to the values reported by Huang, et al., (2007) for cultivars of taro grown in Taiwan. Bhandari, Kawabata, (2006), however, reported lower phytate concentration in different species of wild yam tubers grown in India.

Fermentation of taro flour had resulted in the highest reduction of phytate content. Accordingly, fermentation of raw taro flour from Acc.236000 cultivar registered a higher reduction (86.67%) than the fermentation of taro flour from cultivar Boloso I, which showed 84.75% reduction.

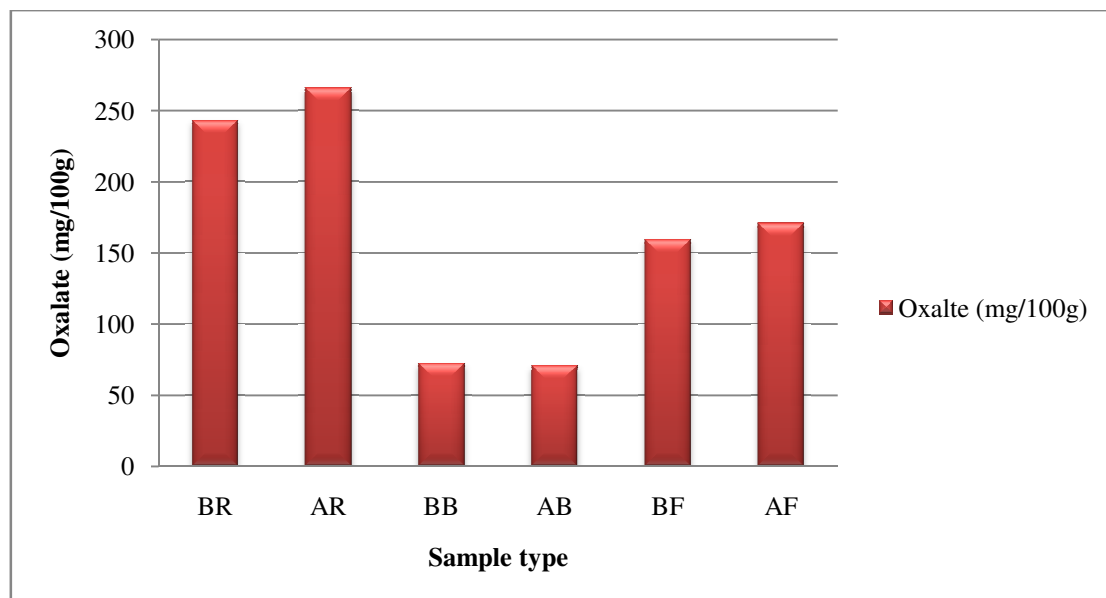


**Fig.4.2 Levels of phytate in raw and processed taro**

High content of phytate in foods is of nutritional significance as not only because phytate phosphorous is unavailable to human, but also it lowers the availability of many other dietary minerals (Sidhuraju and Becker, 2001). Therefore, reduction of phytate obtained in this study is expected to enhance bioavailability of protein and dietary minerals for consumers of taro.

Relatively high oxalate content was observed in the study. Acc.236000 registered the highest oxalate content of 265.88mg/100g which is about 0.3% of the total DM of the plant. But Boloso I had a little lower oxalate content (243.06mg/100g) than Acc.236000. The oxalate content of Boloso I is about 0.24% of the total DM of the tuber.

The oxalate content of raw taro flours was significantly different ( $p < 0.05$ ). But no significant difference on the oxalate content of BB (72.43mg/100g) and AB (70.73mg/100g) was observed at a similar p-value. A significant difference ( $p < 0.05$ ) was observed on the mean oxalate content of fermented boloso (159.42mg/100g) and fermented Acc.236000 (170.72mg/100g).



**Fig.4.3 Levels of oxalate on raw and processed taro**

The oxalate contents of taro cultivars used in this study were within the range of oxalate content of Japanese taro corms reported by, Savage and Catherwood, (2007), Nip, *et al.*, (1989) and Huang *et al.*, (2007). But the values are lower than the oxalate content of taro and sweet potato reported by Noonan and Savage, (1999). However, the obtained oxalate content of taro cultivars were found to be higher than the values reported by Jrrarat *et al.*, (2007) for taro grown in Thailand, Akpan and Umoh, (2004) for Tania in Nigeria and Bhandari, Kawabata, (2006) for wild yams in India .

Boiling had shown the highest reduction of oxalates in taro. Accordingly, boiling of taro had reduced the oxalate contents by 70.9% and 73.4% for boloso I and Acc.236000 respectively. The results obtained in this study agreed with that of Iwuoha and Kalu, (1995), who reported 65.7-82.1% reduction of oxalates by boiling. The reduction of oxalates during boiling may be due to its solubility in boiling water. As indicated by Albihn and Savage, (2001), boiling may cause

considerable skin rupture and facilitate the leakage of soluble oxalates into cooking water; this may be the possible reason to the observed high reduction in oxalate level upon boiling.

Fermentation of taro flour also resulted in a significant reduction of oxalate. The reduction of oxalate almost similar for both cultivars 35.79% and 34.41% for boloso I and Acc.236000, respectively. Carpenter, and Steinke, (1983) reported that the reduction of oxalates of taro was observed in an aerobic fermentation.

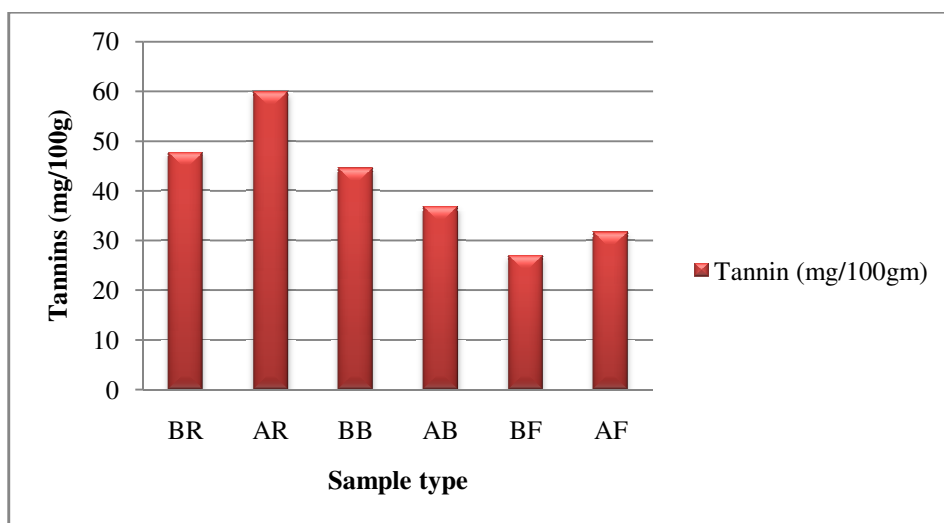
Oxalates are major antinutritional factor present in taro (FAO, 1990). The high oxalate content found in raw taro renders its full utilization. Oxalates can have deleterious effect on human nutrition and health particularly by decreasing calcium absorption and aiding the formation of kidney stone (Noonan and Savage, 1999). Therefore, the reduced oxalate content on boiled taro tubers could have positive impact on the health of the consumers; particularly the reduction of oxalate levels by boiling is expected to enhance the bioavailability of essential minerals of taro and reduce the risk of kidney stone formation among consumers. The reduction of oxalate using boiling up to more than 70% in this study could contribute significantly in full utilization of the potential of taro.

Tannins were long known to exert negative effect on the bioavailability of proteins, minerals particularly iron. In the present study varying amount of tannins were obtained in both cultivars of taro which were investigated. The amount of tannins for raw and processed taro is shown in (Table 4.5). Raw Acc.236000 flour had the highest tannin content of (59.92mg/100g) followed by raw Boloso I flour (47.69mg/100g) and analysis of variance conducted on tannin contents of these two flours had shown that a significant difference existed between them ( $p < 0.05$ ). The difference in tannin content between the two cultivar could be the response of cultivar difference. No significant difference ( $p > 0.05$ ) in tannin contents was obtained between boiled samples of

both cultivars. However, the tannin content of flours obtained from fermentation of raw taro flours was significantly different ( $p < 0.05$ ).

Both processing methods, boiling and fermentation had a significant effect on the tannin content of taros from the two cultivars studied. But fermentation resulted in the higher reduction of tannin than boiling. Accordingly, the tannin content of taros reduced by 38.59% and 43.52% for Acc.236000 and Boloso I, respectively upon fermentation from their respective raw form. Boiling of taro registered 6.69% and 38.63% reduction for boloso I and Acc.236000, respectively.

The observed decrease in tannin content due to boiling may be the leaching out of hydrolysable tannin in the boiling water. The highest reduction of tannin brought about by fermentation of taro flour could be attributed to the action of enzymes excreted by the microorganisms which were involved in the fermentation process.



**Fig 4.4 Tannin content of raw and processed taro**

The range of values obtained for tannins concentrations in this study (47.69-59.92mg/100g) were far below 640mg/100g reported by Akpan and Umoh, (2004) for Tania.

Foods rich in tannins are considered to be of low nutritional value because they precipitate proteins, inhibiting digestive enzymes and Fe absorption and affect the utilization of vitamins and minerals from meals (Tinko and Uyano, 2001). The tannins contents of taro in the present study are low to bring about adverse effect on the consumers.

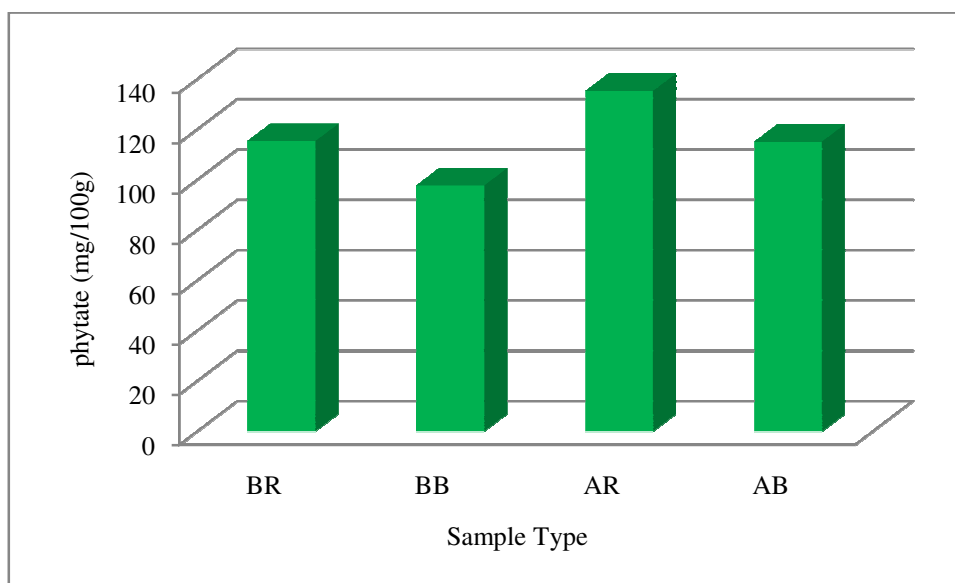
No cyanide was detected in any of the cultivars considered in this study. Therefore the absence of cyanide is an advantage because consumption of these cultivars of taro may not lead to the risk associated with food induced toxicity of cyanide.

## 5. Evaluation of the Effect of Different Processing Methods on Antinutritional Factors of Taro.

### 5.1 Effect of Boiling on Antinutritional Factors

#### 5.1.1 Effect of boiling on Phytate content.

Boiled taro had resulted in a decrease of phytate content from the raw flours. Accordingly boiling of Boloso I had resulted in 15.27 % reduction and Acc.236000 registered a little lower reduction 14.93% from their respective raw form. (Fig 5.1) shows the effect of boiling on the phytate content.



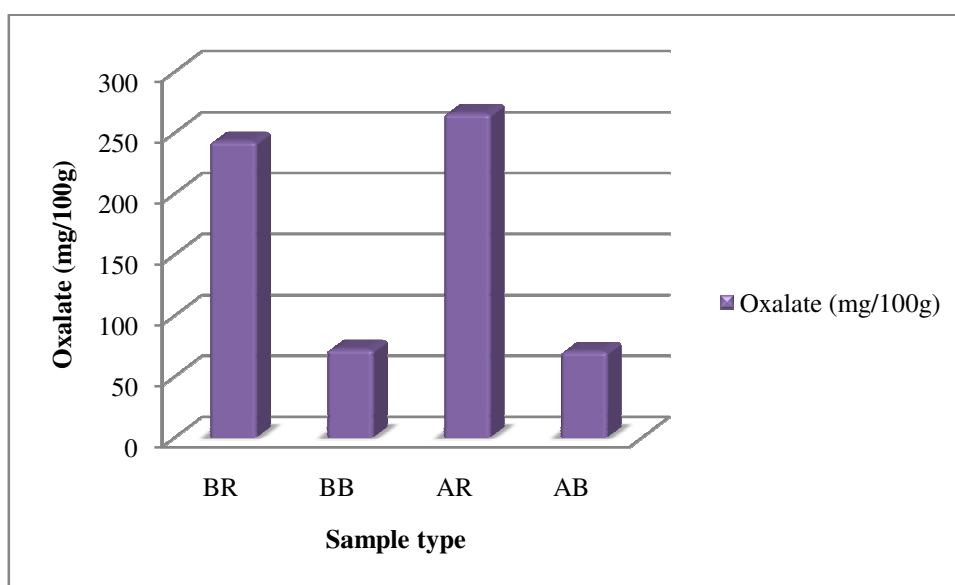
**Fig 5.1 Effect of boiling on the phytate content**

Because phytate is heat-stable, significant heat destruction of phytate during cooking is not expected to occur. Therefore, considerable phytate dephosphorylation during cooking only takes place either by discarding the cooking water or by enzymatic phytate hydrolysis due to the action of the intrinsic plant phytases during the early part of the cooking phase. Heating for prolonged

times at elevated temperatures lead to a progressive inactivation of the endogenous enzymes (Greiner and Konietzny, 2006).

### 5.1.2 Effect of Boiling on Oxalate Content

Boiling resulted in a very high reduction in the oxalates content of both cultivars studied. Accordingly, boiling of taro had reduced the oxalate contents by 70.9% and 73.4% for boloso I and Acc.236000 respectively. Fig 5.2 shows the effect of boiling in the oxalate content of taro.



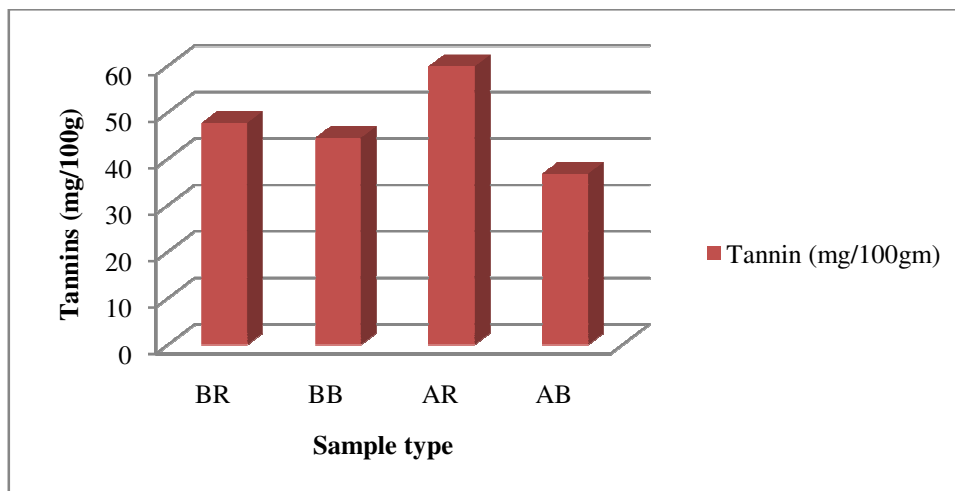
**Fig. 5.2 Effect of boiling on the oxalate contents of taro**

Boiling was effective in the reduction of oxalates in taros of both cultivars in the present study. The reason for this reduction could be the leaching out of soluble oxalates in to the cooking medium.

### 5.1.3 Effect of Boiling on the Tannin Content of Taro

The tannin content of taro both in raw and processed samples was discussed in the discussion part of chapter 4. And the values were also presented in Table (4.5). According to the results obtained

boiling has a less pronounced effect on the tannin content of taro. This may be due to the stability of tannin in heat. Fig 5.3 below shows the effect of boiling on tannin content.



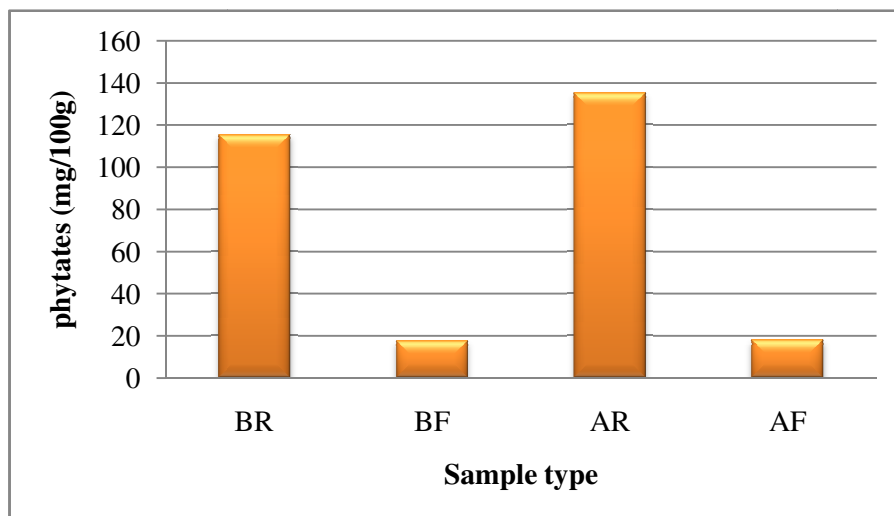
**Fig.5.3 Effect of boiling on tannin contents of taro**

When we evaluate boiling for reduction of antinutritional factors in taro the greatest effect of boiling was seen in the reduction of oxalate. As discussed in chapter four the reduction of oxalate was more than 70% of its initial content.

## **5.2 Effect of natural Fermentation on the Reduction of Antinutrients in Taro**

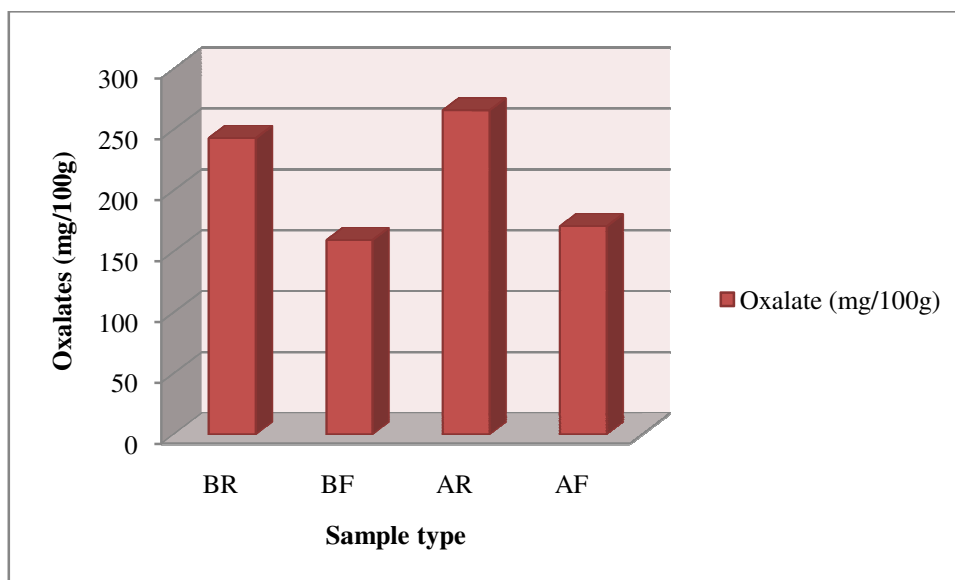
### **5.1 Effect of Fermentation on the Reduction of Phytate**

The greatest effect of fermentation was seen in the reduction of phytate in both cultivars of taro. The reduction was more than 85% of the initial values of phytate in the raw samples. Fig. 5.4 shows the effect of fermentation on phytate values.

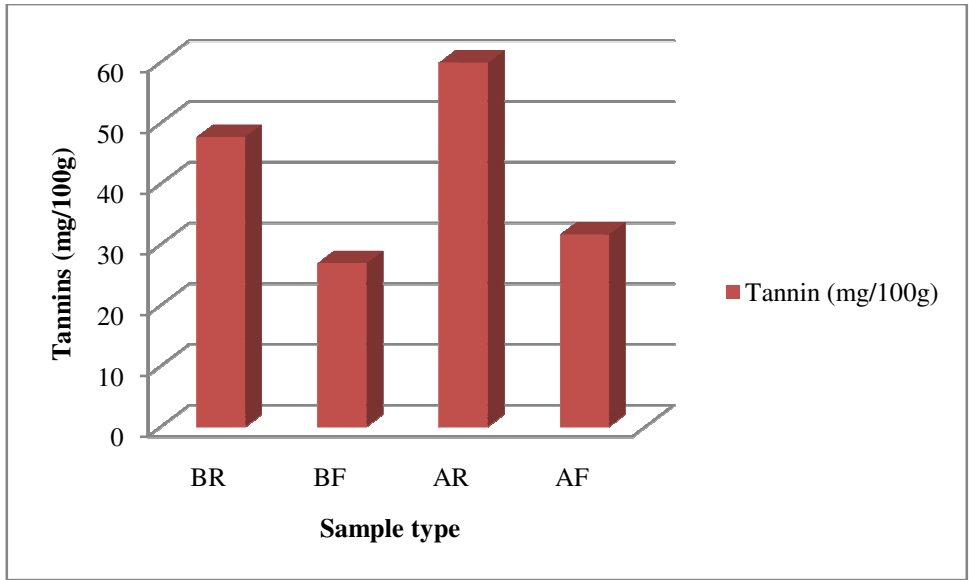


**Fig. 5.4 Effect of fermentation on phytate contents of taro**

The effect of fermentation on oxalate and tannin is also shown in Fig. 5.5 and 5.6. From all the charts we can understand that fermentation was effective in reduction of phytate as compared to the reduction of other antinutritional factors



**Fig 5.5 Effect of fermentation on oxalate content of taro**



**Fig 5.6 Effect of fermentation on tannin content of taro**

In general, the results of the present study showed that both processing methods results in significant reduction of antinutritional factors contents in taro. However the effect of processing methods were not seen to be equally effective in reducing the different antinutritional factors found in taro. Therefore evaluating the processing methods in the present study showed that boiling was effective processing method in reducing oxalate levels in taro while fermentation was very effective in reducing phytates and tannins as compared to boiling process.

## **6. Conclusion**

### **6.1 Conclusion**

From the results of the present study it was understood that taro is an excellent source of dietary energy, essential minerals, and some vitamins that are important for normal functioning of the body. However, taro also contains some antinutritional factors such as oxalates and phytates which can limit the utilization of taro nutrients for human consumption and animal feed. There are a number of studies which are conducted on taro in different countries. The results of the studies showed that both the nutritional and antinutritional components of taro vary from place to place and also from variety to variety (cultivar to cultivar) and varies among agronomic practices. The results of the present study showed that the nutritional value of taro could be significantly affected by the presence of some antinutritional factors contained in it. The levels of these antinutritional factors are also showed significant difference between the cultivars.

From the study it can be concluded that taro is an excellent source of carbohydrate based dietary energy. Processing methods enhances the availability of nutrients in taro by decreasing the antinutritional factors including oxalate, phytate and tannin. The absence of cyanide in both cultivars is one good advantage for consumers of taro since cyanide has an adverse effect on the health of consumers.

The traditional processing method was found to be effective in the reduction of oxalate, which is the major antinutritional factor in taro.

In the study the effect of fermentation was found to be highest in the reduction of phytate contents found in taro. The level of tannin found in taro was found to be low to cause significant effect in the nutritional status of consumers of taro.

The two processing methods significantly affected most functional and physicochemical properties.

The difference observed in the parameters studied could be attributed to many factors including the difference in cultivar, climate, soil type and methods used in the determination of these parameters.

From the study it can be concluded that the improved taro cultivar “Bolosso I” which is released by AARC is the better one in terms of its relatively low level of anti nutritional factors.

Acc.236000 was superior in the nutritional content than, Boloso I, however it was found that all the studied antinutritional factors are significantly higher than that are found in Boloso I. Although this cultivar contains high levels of antinutritional factors, all processing methods were found to be more effective in this cultivar than Boloso I.

Quantitative difference in the concentration of antinutrients, physicochemical properties, functional properties of taro cultivars were evident.

## **6.2 Recommendations for Further Study**

Until recently most agricultural research centers found throughout the country focused on the improvement of the yield, improving pest and disease resistance of the plant, shortening the harvesting time of crops etc. However, evaluation of the crops for their nutritional improvement and reduction of antinutritional factors did not get enough attention.

After thoroughly investigating the situations in the country the following recommendations can be made:

1. Agricultural research centers should work in collaboration with other bodies who work in similar area.
2. Effective processing methods other than studied in this study should be assessed
3. In order to prevent the possible nutritional impacts on consumers of taro from other antinutritional factors, such as trypsin inhibitors, amylase inhibitors and others, the crop should be investigated for these antinutritional factors.
4. Taro is an excellent source of carbohydrate in the form of starch. Therefore determining the quality and quantity of starch found in the two Ethiopian taro cultivars could be one area which needs investigation.
5. The dynamics of fermentation process, the type of microorganisms involved in the natural fermentation of taro should be determined, so that we can isolate proper starter culture.
6. Controlled fermentation of taro using an appropriate starter culture should be done for comparison purpose.
7. Sensory analysis should be done in order to evaluate the effect of processing on the acceptability of the product.

8. Consideration should be given for more recent methods (like, using HPLC ) of analysis for determination antinutrients in taro so that a more accurate and precise data could be obtained.
9. Enzymatic degradation of antinutrients using microbial strains from local endogenous fermented foods needs further investigation. The possibility of using probiotics which can break down the antinutrients could bring desirable benefits.
10. Investigation of protein and starch digestibility of taro flour requires further study.
11. Industrial utilization of taro for different value added product needs further research.

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Annex 1. Questionnaire

**ADDIS ABABA UNIVERSITY**  
**SCHOOL OF GRADUATE STUDIES**  
**FOOD SCIENCE AND NUTRITION PROGRAM**



**QUESTIONNAIRE FOR FOCUSED GROUP DISCUSSION**

**IDENTIFICATION**

**NAME:** ADANE TILAHUN GETACHEW

**FACULTY:** SCIENCE

**DEPARTMENT:** FOOD SCIENCE AND NUTRITION PROGRAM

**MAJOR:** FOOD SCIENCE AND NUTRITION

**ADVISOR:** DR. ENG. SHIMELIS ADMASSU

**CO-ADVISOR:** Prof. NIGUSSEI RETTA

**TITLE OF THESIS:** EFFECT OF PROCESSING ON SOME PHYSICOCHEMICAL  
PROPERTIES AND ANTINUTRITIONAL FACTORS OF TARO  
(*Colocasia esculenta*) GROWN IN ETHIOPIA

## 1. ADDRESS

Name	_____
Sex	male <input type="checkbox"/> female <input type="checkbox"/>
Age	_____
Region	_____
Wereda	_____
Kebele	_____
Occupation	Farmer <input type="checkbox"/> Agronomist <input type="checkbox"/>
Others(specify)	_____
	_____
	_____
	_____

## 2. INFORMATION ON ORIGIN OF TARO

a) What was the geographical origin of TARO?

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

b) When was it introduced in the region?

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

### 3. ABOUT TARO

a) What is its scientific name?

*Colocasia esculenta* (L.) Schott var. *esculenta*;

*Colocasia esculenta* (L.) Schott var. *antiquorum*

Others

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b) What are the existing varieties of Taro?

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c) what is the local name of Taro?

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### 4. INFORMATION ON AGRONOMIC PRACTICE OF TARO

a) What is the farmers planting season?

Mehir

summer

Spring

Others \_\_\_\_\_

b) What is the planting date (month)?

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c) What altitude range is suitable for its growth?

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d) What is the total rain fall amount it requires?

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e) What climatic (weather) conditions are suitable for its harvest?

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f) What type of soil favors its growth?

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g) Is any fertilizer enhancement required for its harvest?

Yes

No

h) What are the pests that commonly attack Taro?

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i) Does it require pesticide for its harvest?

Yes

No

j) What kind of pesticide do you use commonly?

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j) Comparing with other commonly harvested root crops does Taro have an advantage?

Yes  No

i) If the answer for the above question is yes, what are the advantages it has over the others?

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**5. INFORMATION ON ITS YEILD AND COST**

a) What is the maximum annual yield per hectare?

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b) Is there any post harvest loss? If there how much?

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c) If the answer for the above question is yes, what are the main causes of the loss?

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d) What is the current market price of Taro?

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## 6. THE CONSUMPTION OF TARO IN THE SOCIETY

a) Can Taro be edible food source?

Yes  No

b) If the answer for the above question is no, what limits its consumption?

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c) If the answer for the question (6a) is yes, what are the main food items that can be prepared from it?

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d) What are the main traditionally used processes to make it edible?

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e) What are the effects of these processes on the raw Taro? (i.e. palatability, reduction acidity, etc)

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f) What are the other uses of Taro for the local community?

Feed  Ornamental purpose

Others \_\_\_\_\_

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**8. What kind of studies have been conducted on the crop so far?**

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**8. ANY INFORMATION THAT YOU WOULD LIKE TO ADD.**

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**THANK YOU**

## DECLARATION

I, the under signed, declare that this thesis work is my original work and that all source of materials used for the thesis have been correctly acknowledged.

Name: Adane Tilahun\_\_\_\_\_

The thesis has been submitted with our approval as supervisor.

Dr.Eng.Shimelis Admassu\_\_\_\_\_

Prof. Nigussie Retta\_\_\_\_\_

Place and submission: School of Graduate Studies, Addis Ababa University

Addis Ababa, Ethiopia, June 2009