

**EFFECT OF PROCESSING METHOD ON THE PROXIMATE
COMPOSITION, MINERAL CONTENT AND ANTINUTRITIONAL
FACTORS OF TARO (*Colocasia esculenta, L.*) GROWN IN ETHIOPIA**

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ABSTRACT

Although taro is widely grown in Ethiopia, it is an underutilized crop and little is known about its proximate and micro-element composition and the antinutritional factors of the raw, boiled and fermented products. Boiling and fermentation processing techniques are widely used in the country, especially within the rural community of the Southern region where the crop grows widely. A cultivar of taro grown in the country was analyzed for proximate and mineral composition and antinutritional factors. An investigation was also made on the effects of boiling and fermentation on the nutritional contents. Protein, fat, fiber, total ash and utilizable carbohydrates, respectively were found to be 6.43, 0.47, 2.63, 4.82 and 85.65%, while the Gross Energy was 372.55 Kcal/100g. The contents of the micronutrients namely: Fe, Zn, Mg, Ca, Na, P and Mn were 5.86, 43.08, 7.24, 45.23, 13.81, 7.77 and 3.61 mg/100g, respectively. Phytate for the raw product was 115.43 while oxalate and tannin were 243.06 and 47.69 mg/100g, respectively. Cyanide was not detected in all the samples. There was a significant difference ($p < 0.05$) in the contents of the proximate and mineral composition and antinutritional factors during boiling and fermentation. The protein content was lower by 9.37% and 8.46%, respectively, in the boiled and fermented products, under the sampling and processing conditions used in the study. The crude fat content was significantly different ($p < 0.05$) from the crude fat content of the boiled product which was 0.87%. On the other hand, analysis of variance conducted showed that the fiber content of raw sample was significantly different from the fermented samples. Fermentation resulted in a lower level of fiber which was 6.44% and phytates of about 84.75%. Boiling of taro resulted in a higher value of oxalate (70.9%). The data presented in this paper provide an evidence of the potential of Boloso I (which is one variety of taro) to serve as a nutrient dense product for the Ethiopian population provided that the techniques of its processing are optimized.

Key words: Ethiopia, Taro, Oxalates, Phytates

INTRODUCTION

Taro (*Colocasia esculenta*, L) is a 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” and appear to be cultivated in Ethiopia, where they are known without differentiating between them as “Godere” (Amharic: Ethiopian working language) and “Boina” (Wolaitigna: a language of a tribe (Wolaita) in Southern Ethiopia where taro is widely consumed) [1].

Taro is one of the most nutritious and easily digested foods. Like many other root crops, taro corms are high in carbohydrate in the form of starch and low in fat and protein [2]. 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 [2]. When eaten regularly, taro corm is a good source of calcium and iron. Taro leaves are an excellent source of β -carotene, calcium, fiber, and vitamins C and B₂ (riboflavin), and also contain vitamin B₁ (thiamin) [2]. In addition, taro contains about 7% protein on a dry weight basis. This is more than that found in 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 [3].

Like most foods of plant origin, taro contains a variety of anti-nutritional and toxic components such as oxalates, phytates, trypsin and amylase inhibitors, tannins and cyanide. Therefore, it is advisable to process taro before consumption [4, 5].

Although taro is widely growing in Ethiopia, it is an underutilized crop and little is known about its proximate and micro-element composition and the antinutritional factors of the raw, boiled and fermented products commonly used [6]. An attempt was made to determine the effects of boiling and fermentation, commonly practiced in Ethiopia, on the proximate composition, mineral content and antinutritional factors of taro (variety Boloso I) cultivated.

MATERIALS AND METHODS

Sample collection

Samples were collected from Areka Agricultural Research Center (A town located 300 km South - West of Addis Ababa, Ethiopia). All the samples were harvested within 8-10 months of planting (the maturation period of taro). The taro samples selected contained large, middle and small corm (cormels) sizes that were not damaged during harvest and which were not attacked by pests. The samples were kept in an ice box of about 5°C and were transported to the Food Science and Nutrition Program Laboratory of Addis Ababa University in the same day.

Preparation of taro flour

Samples five corms were manually cleaned to remove foreign matter adhering using running tap water, 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.

Boiling of Taro

Five Taro corms were thoroughly cleaned using a running tap water. About 500g of cleaned and washed samples were placed in a cooking utensil and 1500ml of water was added to it. Samples were boiled for 45 minutes in a range of 92 – 95°C. Then, the tubers were hand peeled and sliced in to approximately 0.5mm thick and placed on a stainless steel tray and allowed to dry in an oven at 50°C overnight. The dried taro chips were converted to flour using a miller and sieved to pass through 60 mesh sieve.

Fermentation of taro flour

About 100g of taro flour was mixed with 300ml of distilled water in 1000ml conical flask and the flask covered with aluminum foil and allowed to ferment naturally (spontaneously) at room temperature for 72 hours. Finally, the supernatant was discarded and the slurry transferred into glass bowls and placed in oven to dry overnight at 50°C to a constant weigh and was then milled.

Analysis of proximate composition

Moisture content, total ash, crude protein, crude fiber, and crude fat of the raw, boiled and fermented taro flours were determined using the methods developed by the Association of Official Analytical Chemists (AOAC) [7]. The methods, respectively, were 925.09, 923.03, 979.09, 962.09, and 4.5.01 in which triplicate analysis was conducted in all cases. Utilizable carbohydrate content was calculated by difference with the exclusion of crude fiber [7]. Gross energy content was calculated using the following formulae:

Gross energy (Kcal) = (9 x crude fat) + (4 x crude protein) + (4 x utilizable carbohydrate)

Mineral Analysis

Upon ashing for the determination of the total ash content 3 drops of 1M HNO₃ acid was added to the sample in each of the crucibles. 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, 4-555 Wentworth Street East Oshawa, Ontario, L1H 3V8, 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, b, concentration in ppm of sample and blank solution, and V, volume in mL of the extract Osborne and Voogot [8].

Total phosphorous determination

The sample solutions prepared for mineral determination were used for phosphorous determination. One ml of the clear extract 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.

Analysis of Antinutritional factors

Oxalate analysis

The oxalate contents of both raw and processed taro flours were determined using the method of Iwuoha and Kalu [9]. This method involves the following three steps: digestion, oxalate precipitation and permanganate titration.

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 .

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 NH₄OH 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% CaCl₂ 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) H₂SO₄ solution.

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 KMnO_4 solution to a faint pink color which persisted for 30 s. The calcium oxalate content was calculated using the formula:

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

where T is the titre of KMnO_4 , (ml), Vme is the volume-mass equivalent in which 1 cm^3 of 0.05 M KMnO_4 solution is equivalent to 0.00225 g anhydrous oxalic acid), DF is the dilution factor 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 KMnO_4 in oxalate (KMnO_4 redox reaction. (5)) and m_f is the mass of flour used.

Phytic Acid

The phytate content was determined according to method described by Latta and Eskin[10], and later modified by Vaintraub and Lapteva [11]. 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. 1mL 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.

Tannins analysis

Tannins were determined using the method of Burns [12]). 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. One ml 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). The concentration of tannins was calculated using D-Catechin standard curve and results were expressed as of D- Catechin equivalent in mg per 100g dry weight. Cyanide was determined by the AOAC Official method 49.49 [13].

Statistical analysis and data processing

One-way analysis of variance (ANOVA) was conducted on each of processing methods 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.

RESULTS

Proximate Compositions

The proximate composition of the raw and processed taro of variety Boloso I is presented in Table 1. The protein, crude fat, crude fiber, ash, moisture and the utilizable carbohydrate respectively were 6.44, 0.47, 2.62, 4.82, 0.54 and 85.65%. The gross energy was 372.56 Kcal/100g DM. Boiled taro contained protein of 5.83, crude fat of 0.87, crude fiber of 3.21, ash of 4.40, moisture content of 10.19, total carbohydrate of 85.63% and gross energy of 373.69 Kcal/100g DM, while the fermented flour contained 6.98, 0.41, 2.46, 5.44, 6.05 84.70%, respectively and gross energy of 370.46Kcal/100g.

Mineral Composition

Eight different kinds of minerals were analyzed for their concentration in dry weight basis. Table 2 shows the mineral composition of raw, boiled and fermented taro flours. Raw Boloso I had Fe (5.86mg/100g), Zn(43.08mg/100g), Ca(45.23mg/100g), Na (13.81mg/100g), Mg (7.24mg/100g), Cu (0.43mg/100g), Mn (3.61mg/100g) and P (7.77mg/100g). The fermented taro samples show a significant difference ($p \leq 0.05$) in their Fe, Zn, Ca and Na content, where the values are reduced when compared to the raw and boiled taro. The value of phosphorus however, increased in the fermented and boiled products.

Antinutritional Factors

Significant quantities of antinutritional factors namely; phytate, oxalate and tannin were found in both raw and processed taro flours (Table 3), while cyanide was not observed in any of the samples. The mean phytate content of raw Boloso I was 115.43mg/100g, while oxalate was found to be 243.06mg/100g. The concentration of tannin was 47.69mg/100g. Boiling and fermentation significantly reduced the values of all the antinutritional factors.

DISCUSSION

Proximate Composition

The protein content of raw taro (variety Boloso I, grown in Ethiopia) exhibited a significant difference when compared to the boiled and fermented products ($p < 0.05$). The value of protein in the boiled products was lower by 9.37%, while during fermentation by 8.46%. The increase in protein content of fermented taro flours could be due to the synthesis of amino acids during the fermentation process [14]. Lower values during boiling are attributed to the de-naturation of proteins and the leaching out of soluble amino acids [15]. The range of the protein content in the present study (6.43% -6.98%) fall within ranges reported earlier [16]. This value, however, is higher than values reported by Aboubakar et al. [17].

The crude fat content of taro cultivars used in this study was higher than the range of fat contents which were reported by Aboubakar et al. for five cultivars of taro grown in Cameroon and Chad, and for five cultivars of taro grown in American Samoa [17, 18]. The crude fat content of raw Boloso I (0.47%) was significantly different ($p < 0.05$) from the crude fat content of the boiled product (0.87%). On the other hand, analysis of variance conducted showed that the fiber content of raw sample was significantly different ($p < 0.05$) from the fermented samples. Fermentation resulted in a lower fiber content by 6.44% and the possible explanation is the enzymatic degradation of the crude fiber as a result of the enzymes excreted by the microorganisms involved in the fermentation process.

The high moisture content of fresh taro corms is a limitation of production and utilization of taro. One possible method to overcome the post-harvest loss is converting the products into flours of low moisture content. On the other hand, the range of the total ash content of taro flours (4.46-5.44%) were higher than the ash contents of taro that were reported by Nip et al. and Huang et al. [18, 19] Our results, however, were lower than the ash content of taro reported by Njoku and Ohia [20]. The observed difference in the ash contents may be attributed to climatic factors, the soil type and the varietal difference. From the high ash contents of the taro samples studied, one can easily understand that taro could contain appreciable quantity of minerals.

From the results it can also be noted that Boloso I is a very good source of carbohydrate (CHO). There was no significant difference ($p > 0.05$) between the CHO content of raw and boiled taro samples. On the other hand, the CHO of fermented taro flours had shown significant difference ($p < 0.05$) from the raw form. It should also be noted that, the range of the values obtained for CHO in this study (close to 85%) were lower than the values reported in other studies and the difference might be attributed to the difference in cultivars, climate and soil type [18]. In addition Gross Energy (GE) (370 - 374Kcal/100g) were very comparable to the GE of maize and higher than GE of cassava, Irish potato, yam, sweet potato and taro and are less than the GE of rice and sorghum [16]. This quantity of energy makes Boloso I one of the most carbohydrate rich foods in supplying high quantity of energy per given mass of food consumed and can be considered as a crop which can contribute to the efforts of the Ethiopian Government to alleviate food and nutrition security.

Mineral Composition

Among the minerals analyzed, the composition of Cu is the least and this is an advantage since Cu is an essential mineral for normal body function in a very small quantity [21]. The values for Mg, Na, P, and Cu are less than the values previously reported by Huang et al. and Nijoku and Ohia [19, 20]. However, Zn in the raw product (43 mg/100gm) was higher. The calcium content of taro cultivars was within the range reported by Huang et al. [19]. In the present study, the concentration of the minerals in the fermented product reduced and this could be attributed to the fact that the supernatant was discarded and not included in the analysis (as is used for consumption traditionally).

Antinutritional Factors

Boiled taro (Boloso I) had lower levels of phytate content compared to the raw flours. Boiling of Boloso I resulted in 15.27% reduction. A higher reduction (about 20%) was observed by Bhandari and Kawabata for wild cultivars of yam upon boiling [5]. The authors suggested that the noticeable decrease in phytate content during boiling may be partly due to either the formation of insoluble complexes between phytate and other components, such as phytate-protein, phytate-protein-mineral or to the inositol hexaphosphate hydrolyzed and penta- and tetra-phosphates. The phytate concentrations observed in unprocessed taro cultivars in this study (115.43mg/100g) were far below the values reported by FAO [15]. However, these values were comparable to the values reported by Huang et al., for cultivars of taro grown in Taiwan [19]. Fermentation of taro flour resulted in the highest reduction of phytate content (by 84.75%). High content of phytate in foods is of nutritional significance only because phytate phosphorous is unavailable to human, but also lowers the availability of many other dietary minerals such as iron and zinc [22]. Therefore, low value as of phytate obtained in this study is expected to enhance the bioavailability of protein and dietary minerals for consumers of taro. The reduction of phytate is due to microbial action in the fermentation process.

Relatively high oxalate content was observed in the current study. Boloso I had an oxalate content of 243.06mg/100g and this is about 0.24% of the total dry mass of the tuber. The oxalate contents of taro cultivar used in this study were within the range of oxalate content of taro corms reported by various authors [18, 19, 23]. The values were lower than the oxalate content of some taro cultivars and sweet potato [24]. However, the obtained oxalate content of Boloso I was found to be higher than the values reported for taro grown in Thailand [25]. Boiling had shown the highest reduction of oxalates in taro. Accordingly, boiling of taro had reduced the oxalate contents by 70.9% for Boloso I. The results obtained in this study agreed with that of Iwuoha and Kalu who reported 65.7-82.1% reduction of oxalates by boiling [9]. The reduction of oxalates during boiling may be due to its solubility in boiling water. As indicated by Albihn and Savage boiling may cause considerable skin rupture and facilitate the leakage of soluble oxalates into cooking water [26]. Fermentation of taro flour also resulted in a significant reduction of oxalate (by 35.79%). Reduction of oxalates of taro was observed during aerobic fermentation.

Oxalates are major antinutritional factors present in taro [15]. The high oxalate content found in raw taro restricts its full utilization. Oxalates can have deleterious effect on human nutrition and health particularly by decreasing calcium absorption and aiding the formation of kidney stones [24]. 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 stones formation among consumers. In the present study, boiling reduced oxalate by seventy percent.

Tannins were long known to exert negative effect on the bioavailability of proteins, minerals and particularly iron. Both processing methods had a significant effect on the tannin content of taros, where fermentation resulted in the greater reduction (by 43.52%) and boiling by 6.69%. The observed decrease in tannin content due to boiling might be attributed to the leaching out of hydrolysable tannin in the boiling water. The highest reduction of tannin brought about by fermentation of taro flour could also be attributed to the action of enzymes. Foods rich in tannins are considered to be of low nutritional value because they precipitate proteins, inhibiting digestive enzymes and iron absorption and affect the utilization of vitamins and minerals from meals [27]. The tannins contents of taro in the present study were found to be too low to cause any adverse effect on the consumers.

CONCLUSION

Boloso I can be a good source of dietary energy and essential minerals, provided the traditional processing techniques are improved. On the other hand, it contains some antinutritional factors such as oxalates and phytates which can limit the utilization of taro nutrients for human consumption and animal feed.

Table 1: Proximate composition of raw and processed taro flours (Boloso I grown in Ethiopia)

Sample Type	Protein(%)	Fat (%)	Fiber (%)	Ash (%)	Moisture (%) [†]	Utilizable Carbohydrate (%)	Gross Energy (Kcal/100 g DM)
Boloso I Raw	6.43 ±0.01 ^d	0.47±0.08 ^a	2.63±0.05 ^a	4.82±0.04 ^a	0.54±0.03(70.9) ^a	85.65 ±0.07 ^a	372.55 ±0.41 ^a
Boloso I Boiled	5.83 ±0.06 ^e	0.87±0.04 ^c	3.21±0.01 ^c	4.46±0.22 ^a	10.19 ±0.02 ^c	85.63 ±0.28 ^a	373.68 ±0.62 ^c
Boloso I Fermented	6.98 ±0.00 ^c	0.41±0.001 ^a	2.46±0.002 ^b	5.44±0.11 ^b	6.05 ±0.004 ^e	84.74 ±0.10 ^b	370.46 ±0.49 ^d

Values are means of triplicates analysis ± standard deviations

^{a-e} values with different superscripts in the same columns are significantly different at P<0.05

[†]Value in bracket for moisture content is the moisture content of fresh taro tubers.

Table 2: Mineral composition of raw and processed taro flours (Boloso I grown in Ethiopia)

Type of Minerals	Sample Type		
	Boloso I Raw	Boloso I Boiled	Boloso I Fermented
Fe	5.86 ±0.7471 ^a	6.03 ±0.02 ^a	4.13 ±0.04 ^b
Zn	43.08 ±0.20 ^a	14.77 ±0.16 ^c	11.65 ±0.06 ^e
Ca	45.23 ±2.11 ^a	47.49 ±0.55 ^c	42.99 ±0.05 ^e
Na	13.81 ±0.10 ^a	15.74 ±0.59 ^c	12.29 ±0.04 ^d
Mg	7.24 ±0.03 ^a	8.23 ±0.05 ^b	8.94 ±0.01 ^c
Cu	0.43 ±0.04 ^a	0.59 ±0.10 ^b	0.43 ±0.03 ^a
Mn	3.61 ±0.17 ^a	1.52 ±0.07 ^b	3.99 ±0.02 ^d
P	7.77±0.71 ^a	11.09±1.82 ^b	15.54±0.33 ^c

*All values are means of triplicate analysis ±standard deviation

^{a-e} Values which are followed by different letters of superscripts in the same row are significantly different

Values are expressed in mg/100g of dry weight basis

Table 3: Levels of antinutritional factors of raw and processed taro flours (Boloso I grown in Ethiopia)

Sample Type	Phytate (mg/100g)	Oxalate (mg/100g)	Tannin (mg/100g)	Cyanide (mg/100g)
Boloso I Raw	115.43 ±2.22 ^a	243.06 ±2.74 ^a	47.69 ±2.06 ^a	ND
Boloso I Boiled	97.79 ±5.03 ^c	72.43 ±0.82 ^c	44.50 ±5.13 ^a	ND
Boloso I Fermented	17.60 ±0.34 ^d	159.42 ±1.80 ^d	26.94 ±0.80 ^d	ND

^{a-d} means with different superscripts within the same column are significantly different at p<0.05

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