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Effect of Pre-Gelatinization on Nutritive and Non-Nutritive Constituents of Taro (*Colocasia Esculenta L*) Corm

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Abstract

The study was conducted using factorial combination of two independent variables (taro leaf varieties and processing methods) with three replications in a completely randomized design (CRD) at the same significant level ($\alpha<0.05$). The analysis undertaken in this study was leaf proximate composition, mineral concentration and anti-nutritional factors of samples processed as pre-gelatinized taro starch with and without peel. The moisture content (%) between taro varieties in this study was ranged from 6.218 ± 1.835 to 4.218 ± 2.162, crude protein (CP%) from 12.127 ± 2.326 to 10.498 ± 2.384, crude fat (EE%) from 3.421 ± 0.659 to 2.608 ± 1.116, crude fiber (CF%) from 2.801 ± 0.938 to 2.110 ± 0.262, total ash (TA%) content ranged from 3.886 ± 0.794 to 3.296 ± 0.494, carbohydrate content (%) from 75.489 ± 4.436 to 72.534 ± 2.107, amylose content (%) ranged from (12.894 ± 0.679) to (13.557 ± 0.490), beta (β)-carotene content mg/100 g from 2.307 ± 0.162 to 2.107 ± 0.502. The five macro minerals, mg/100 g of Na, K, Mg, P and Ca in this study were significantly ($p<0.05$) different and ranged from minimum 9.716 ± 4.52, 17.743 ± 1.364, 7.683 ± 0.185, 0.736 ± 0.307 and 11.280 ± 4.78 to maximum13.443 ± 5.704, 18.923 ± 1.543, 8.233 ± 0.830, 1.063 ± 0.307, 16.280 ± 4.68 values, respectively and micro minerals like Zn, Fe, and Cu (mg/100 g) were significantly ($p<0.05$) varied from minimum 8.526 ± 2.418, 88.773 ± 17.205 and 0.296 ± .125 to maximum 11.310 ± 2.674, 104.303 ± 16.109 and 0.403 ± 0.096 values, respectively. The anti-nutritional content like condensed tannin, phytate, mucilage, oxalate, lectin, protease inhibitor and alpha (α)-amylase inhibitor were determined and their inhibitory effects were reduced in flour samples pre-gelatinized without peel. From the general trend observed in this study most of the analyzed samples that boloso-1 taro variety subjected to pre-gelatinization without peel provided better proximate (except CF%), mineral, functional and lower anti-nutritional content than that of the local taro variety.

Keywords: Anti-nutritional factors; Boloso-1; Taro starch; Pre-gelatinization and proximate composition

Introduction

Taro (Colocasia esculenta L.) a family of Aracea is cultivated for its edible corms used as a subsistence food by millions of people in developing countries [1]. Root and tuber crops are second only in importance to cereals as a global source of carbohydrates. The corm of taro contains more than twice the carbohydrate content of potatoes and yield 135 kcals per 100 g and 11% crude protein (CP) on a dry matter (DM) basis. These reported values are even higher than other root crops like yam, cassava or sweet potato that have a carbohydrate(85%) and CP (11%) content respectively [2]. It contains 85-87% starch on DM basis with small granules size of 3-18 µm and other nutrients such as zinc, vitamin C, thiamin, riboflavin and niacin better than other cereals [3]. Thought, protein and fat content of taro are low but it is high in carbohydrates, fibre and minerals.

Due to lack of appropriate storage and post-harvest handling technologies preserving crops for longer period is very difficult and most rural peoples suffer from malnutrition. For instance, zinc deficiency is currently widespread and affects the health and well-being of populations of the developing countries worldwide and since taro is one of the few non-animal sources of zinc, its utilization should therefore be pursued to help in the alleviation of zinc deficiency which is associated to stunting of children. Characterization of such less domesticated and unexploited food sources from the rural sources is essential to increase food choices and habits that support rural food security. In Ethiopia, root crops are widely grown in the southern part of the country.

In Ethiopia, root crops are widely grown in the southern part of the country. Among the root crops, taro is one of the most important food crop as well as income source to the farmers. Farmers produce taro for their own consumption and considers difficult to store and sometimes wasteful because of spoilage and the demand for taro in urban areas has not gained attention and neglected yet. However, it has a great potential to supply high quality food and one of the cheapest source of energy. Even though taro has many nutritional, economic and health attributes, it has also some anti-nutritional compounds that are harmful to health. Because of these inherent factors of anti-nutritional compounds, taro demand is often unsatisfied which impose serious neglecting in both rural and urban consumers.

Generally, taro is the underutilized root crop in Ethiopia [4]. Underutilized plants when properly brought under use can be goodness to malnutrition. People are eating taro corm as boiled, but there is no awareness about various processing methods that increase the quality and safety of the corm. Njintang et al. [5] stated that taro has not

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gained sufficient research attention with regards to its potential having nutritional, industrial and health importance. In this context, taro corm was evaluated for its nutritional and anti-nutritional components through application of effective processing methods that eliminate the anti-nutritional compounds so as to make the nutrients available; and making taro safe to eat [6].

Therefore, this study was aimed to investigate the anti-nutritional content of taro and whether different improved methods of preparation and processing can reduce dominant anti-nutritional compound when consumed as part of human diet. First taro was processed into a more durable and convenient product to use in rural peoples to maximize their food and nutritional security. Samples in the form of pre-gelatinized flour were analysed for different food functional properties as noted by. In general, this study brought extensive research outputs on how to use taro corm accompanied with appropriate processing methods for human consumption at high level of nutrient sources which have direct impact on improvement of food security and nutrition. Therefore, in the present study, the nutritional (CP, crude fat (EE), total ash (TA), crude fiber (CF), carbohydrate, energy and minerals), anti- nutritional (phytate, tannin, oxalate, mucilage, lectin, protease and alpha-amylase inhibitors) and functional constituents (beta-carotene and total phenols) of pre-gelatinized taro corm flour were determined.

Materials and Methods

Sample source and study sites

Local and boloso-1 taro corm (*Colocasia esculenta* L.) varieties at about 9 months of age were harvested from Areka Agricultural Research Center (AARC), a town located 300 km Southwest of Addis Ababa, Ethiopia. The harvested corm then brought to the Centre for Food Science and Nutrition Laboratory (CFSNL) of Addis Ababa University and Haramaya University where the proximate experiment was conducted. The anti-nutritional components analysis was done at the Ethiopian Public Health Institute (EPHI) central laboratory.

Experimental samples preparation

Corm samples brought to the CFSNL of Addis Ababa University were cleaned, peeled and steeped immediately in a portable tap water at room temperature for 30 minute to prevent the browning of the peeled corm. Following this the peeled corm was again held in portable tap water to remove the surface contaminant, mucilage and then was sliced to 2 mm thickness using a manual kitchen slicer. The sliced samples were then boiled at 95°C for 30 minutes to reduce the trypsin and chymotrypsin inhibitors and to remove the acridity significantly [7]. After which, the water was removed by drying in an oven on aluminum foil lined trays at 105°C for 2 hr [8]. For the second pre-gelatinization to make non peeled corm flour, the taro corm was selected and cleaned then boiled with peel at 110°C for 30 minutes. Following this, the boiled pre-gelatinized taro corm was air cooled and peeled. The peeled pre-gelatinized corm was being sliced to 2 mm thickness using a manual kitchen slicer. After it was dried in an oven at 105C for 2 hr, both the dried samples from the two methods were milled to flour using a hammer mill and then sieved into fine flour particles using a mesh screen sieve of 250 microns size to obtain the pre-gelatinized taro flour. The produced samples was packed in plastic bags and preserved at room temperature until analyzed.

Experimental analysis

Taro corm samples (local and boloso-1 taro varieties flour with and without peel) were analyzed for moisture, CF, TA, EE and CP using AOAC and AACC [2] methods. The total carbohydrates content was determined by difference from other nutrients. The energy density (ED) of local and boloso-1 taro flour samples were calculated with 4 kcal/g for carbohydrates, 4 kcal/g for proteins and 9 kcal/g for crude fat according to Livesey [9]. The five macro minerals such as Na, K, Mg, P, Ca and three micro minerals like Zn, Fe and Cu was analyzed by atomic absorption spectrophotometer according to (AACC, 2000) method. Beta-carotene and total phenolic compounds was determined according to Biswas et al. [10]. Concerning the anti-nutritional content like mucilage, it was determined according to methods modified by Yamazaki, the phytic acid was also determined through phytate phosphorus (Ph-P) analysis according to Plaami and Kumpulainen [11]. The oxalate content of the samples was determined by the method of AOAC [12]. Tannin content was determined using the method of Burns. Lectins, alpha-amylase and protease (trypsin) inhibitors were determined according to Peumans et al.

Statistical analysis

Data were analyzed using the general linear model procedures of Statistical Analysis Systems software. The difference between the treatments was determined by analysis of variance (ANOVA) for factorial experiment in full factorial design and comparison of the mean was done by Duncan's multiple range tests. The statistical analysis was conducted to examine the interaction effects for two independent variables (taro corm varieties and pre-gelatinization methods).

Results and Discussions

Moisture content

The moisture content (%) in this study was ranged from 6.218 ± 1.835a to 4.218 ± 2.162 (Table 1). Moisture content in food sample is an index of stability and determines the appearance, keeping quality and yield of the product [13]. The difference among variety and processing method was significant ($p<0.05$). The moisture content of pre-gelatinized taro starch prepared from Boloso-1 with peel was the highest (6.218 ± 1.835) of all. The lowest (4.218 ± 2.162) moisture content was obtained from the same taro pre-gelatinized without peel. This might be due to the application of dehydration condition remove the majority of water in pre-gelatinized taro without peel than with peel and reduce the final moisture content of the sample [14-16]. The fresh taro corm is the most perishable and can deteriorate within one or two weeks after harvesting. The application of processing is vital and the general trend observed in this study was that the moisture content was found to be lower in pre-gelatinized samples without peel.

Treatments				
Taro varieties	Gelatinization methods	Moisture content	Crude protein	Crude fat
Boloso-1	PGF1	4.218 ± 2.162^{d}	12.127 ± 2.326^{a}	3.018 ± 1.352^{ab}
	PGF2	6.218 ± 1.835^{a}	10.498 ± 2.384^{cd}	2.677 ± 1.219^{c}
Local	PGF1	4.777 ± 3.024^{c}	11.913 ± 2.695^{ab}	3.421 ± 0.659^{a}
	PGF2	5.440 ± 3.095^{b}	10.655 ± 2.655^{c}	2.608 ± 1.116^{cd}
Average mean CV (%)		5.163	11.298	2.931
		3.783	5.328	3.681
Significance level (A × B).		*	*	*

$^{a-d}$ Means within a column with different superscripts differ significantly ($p<0.05$); SD: standard deviation; CV: coefficient of variation; PGF1: pre-gelatinized without peel, PGF2:pre-gelatinized with peel, A: Variety and B: Gelatinization method.

Table 1: Interaction of variety by gelatinization methods on moisture, crude protein and fat contents of taro corm flour samples (%DM basis).

Crude protein content

The CP% in this study was ranged from 12.127 ± 2.326 to 10.498 ± 2.384 (Table 1). The local taro pre-gelatinized with peel contained the highest protein content followed by boloso-1 taro pre-gelatinized with peel. However, the lowest CP was obtained from boloso-1 taro pre-gelatinized with peel samples. This might be because; boloso-1 taro corm contains more soluble proteins and lower moisture that inclined the total solid matters in the flour [17]. The result obtained from this study is consistent with the work of Monte et al. [18] and Castro et al. who did their research on….and come up with…result. From the FAO report stated [1] that taro corm contains about 11% CP on a DM basis which is similar to the present study. The notable findings from this study were the crude proteins value were higher than the reported value might be age at which the corm harvested and processing method applied that reduce protein inhibitory factors and therefore pre-gelatinization applied in the study shows better protein supply.

Fat content

As indicated in Table 1 the crude fat content (%) in this study was ranged from 3.421 ± 0.659 to 2.608 ± 1.116. The crude fat content from this study in percentage differ significantly ($p<0.05$). The fat content of local taro pre-gelatinized without peel composed the highest and the least value was also obtained in the local taro pre-gelatinized with peel. The flour pre-gelatinized form without peel samples in taro varieties provided the highest fat content than that of flour pre-gelatinized form with peel. These, little reduction of fat content was observed in flour pre-gelatinized form with peel samples might be because the presence of peel would decrease the fat extraction and solubility [7,19]. Therefore, the result of this study is similar with the result of [20].

Total ash

The TA% in this study was differing significantly ($p<0.05$). As results presented in Table 1, the total ash content was highest (3.886 ± 0.794) for local taro pre-gelatinized without peel and pre-gelatinized with peel than boloso-1 taro. The ash content of boloso-1 taro pre-gelatinized without peel was lowest (3.296 ± 0.494) value of all. The ash contents from this study were in agreement with the findings reported by Njoku and Ohia [21]. This implies that local taro is better source of ash than that of boloso-1 variety and this finding was consistent with the work of Adane et al. [4] who conducted a research on mineral contents of taro and yam corm.

Crude fiber (CF)

As it can be seen from Table 2, the CF content (%) was ranged from 2.801 ± 0.938 to 2.110 ± 0.262 on DM basis. The result has revealed that CF content variability found among boloso-1 and local taro varieties. The CF contents decreased in pre-gelatinized taro flour without peel samples and boloso-1 taro had lowest values than that of local variety. This might be due to variety difference and the method of processing with peel may be due to the presence of peel add extra fiber composition to the samples [22]. Similarly, other researchers suggested that the CF content of different taro samples was reduced and increased because of different processing methods, processing with peel had an effect on increasing the dietary fiber contents in food [5,22]. For instance, CF content of taro corms subject to drying, backing and fermentation with peel was increased [23].

Total carbohydrate

The total carbohydrate content (%) in this study was ranged from 75.489 ± 4.436 to 72.534 ± 2.107 (Table 2). The carbohydrate content in percentage differ significantly ($p<0.05$). The result from this study revealed that the total carbohydrate content was high in pre-gelatinized with peel than pre-gelatinized without peel in both taro varieties. On the other hand, the highest carbohydrate value was comprised in boloso-1 taro pre-gelatinized without peel and the lowest carbohydrate value was obtained in local taro flour-1. According to the work reported by Lauzon and Kawabata [23]; Jane et al. [24] and Benesi et al. [25]. Therefore, taro can be good source of digestible starch and would supply high carbohydrates.

Energy value

As presented in Table 2 the total energy value (%) in this study was ranged from 376.781 ± 9.870 to 363.157 ± 14.130. The energy contents in percentage differ significantly (p0.05). The highest energy content was existed in boloso-1 taro flour-1. Energy content is associated with carbohydrate content and flour samples with highest carbohydrate held highest energy content (Table 2). The result from this study showed that flour pre-gelatinized without peel of both taro varieties obtained high energy content than that of flour pre-gelatinized with peel samples. According to Olajide et al. [26] taro corm and the processed products could be rich sources of energy. The same with this report, the present study was also indicated that the taro corm could supply high energy value in human diets.

Amylose content

As presented in Table 3 the highest percentage value of taro corm amylose were 13.557 ± 0.490 and the lowest value 12.894 ± 0.679 between the varieties and processing methods of taro corm. Pre-gelatinized flour without peel samples in local taro variety showed greater amylose content than that of boloso-1 variety. In other words, taro starch amylose percentage decreased due to pre-gelatinization with peel and this may be due to decrease rate of amylose component extractions in non-peeled corms (Lewis 1990 and Gordon 2000). Similar findings were also reported [3]. Taro roots are rich in a starch composed of

		Treatments			
Taro varieties	**Gelatinization methods**	**Crude fiber**	**Total ash**	**Carbohydrate**	**Energy value**
Boloso-1	PGF1	2.110 ± 0.262^{c}	3.296 ± 0.494^{bc}	75.489 ± 4.436^{a}	376.781 ± 9.870^{a}
	PGF2	2.666 ± 1.083^{ab}	3.575 ± 0.973^{b}	74.266 ± 5.107^{b}	363.157 ± 14.130^{d}
Local	PGF1	2.637 ± 1.098^{b}	3.886 ± 0.794^{a}	72.534 ± 2.107^{c}	369.436 ± 20.719^{b}
	PGF2	2.801 ± 0.938^{a}	3.825 ± 0.885^{ab}	75.476 ± 4.455^{a}	368.001 ± 20.457^{c}
Average mean CV (%)		2.554	3.646	74.441	369.344
		1.318	1.356	4.854	2.687
Significance level (A × B)		*	*	*	*

[a-d] Means within a column with different superscripts differ significantly ($p<0.05$); SD: standard deviation; CV: coefficient of variation; PGF1: pre-gelatinized without peel, PGF2:pre-gelatinized with peel, A: Variety and B: Gelatinization method.

Table 2: Interaction of variety by gelatinization methods on crude fiber, total ash, total carbohydrate and energy values of pre-gelatinized taro starch samples (%DM basis).

Treatments				
Taro varieties	Gelatinization methods	Amylose content	β-carotene (mg/100 g)	Phenols (mg/100 g)
Boloso-1	PGF1	13.207 ± 1.007^{ab}	2.001 ± 0.420^{b}	6.954 ± 2.335^{c}
	PGF2	13.134 ± 0.995^{b}	2.307 ± 0.162^{a}	8.186 ± 2.403^{ab}
Local	PGF1	13.557 ± 0.490^{a}	2.037 ± 0.466^{ab}	6.921 ± 2.259^{c}
	PGF2	12.894 ± 0.679^{c}	2.107 ± 0.502^{ab}	8.3163 ± 2.16^{a}
Average mean CV (%)		13.198	2.113	7.594
		4.689	6.916	6.447
Significance level (A × B)		*	*	*

[a-d] Means within a column with different superscripts differ significantly (p<0.05); SD: standard deviation; CV: coefficient of variation; PGF1: pre-gelatinized without peel, PGF2:pre-gelatinized with peel, A: Variety and B: Gelatinization method.

Table 3: Interaction of variety by gelatinization methods on amylose, β-carotene and phenoloic contents of pre-gelatinized taro starch samples (%DM basis).

Treatments						
Taro varieties	Gelatinization methods	Na (mg/100 g)	K (mg/100 g)	Mg (mg/100 g)	P (mg/100 g)	Ca (mg/100 g)
Boloso-1	PGF1	13.443 ± 5.704^{a}	18.063 ± 1.911^{b}	7.683 ± 0.185^{b}	0.736 ± 0.307^{bc}	16.280 ± 4.680^{a}
	PGF2	13.420 ± 5.742^{a}	18.750 ± 1.830^{a}	8.113 ± 0.925^{ab}	0.940 ± 0.494^{ab}	13.110 ± 7.570^{c}
Local	PGF1	9.716 ± 4.523^{d}	18.923 ± 1.543^{a}	8.233 ± 0.830^{a}	0.860 ± 0.494^{b}	14.390 ± 7.580^{b}
	PGF2	10.820 ± 6.434^{c}	17.743 ± 1.364^{c}	8.200 ± 0.867^{a}	1.063 ± 0.307^{a}	11.280 ± 4.780^{d}
Average mean		11.85	18.37	8.057	0.9	13.765
CV (%)		5.356	6.774	6.486	1.854	3.752
Significance level (A × B)		*	*	*	*	*

[a-d] Means within a column with different superscripts differ significantly (p<0.05); SD: standard deviation; CV: coefficient of variation; PGF1: pre-gelatinized without peel, PGF2:pre-gelatinized with peel, A: Variety and B: Gelatinization method.

Table 4: Interaction of variety by gelatinization methods on macro mineral contents of pre-gelatinized taro corm samples (%DM basis).

amylose 28% and amylopectin 72% [27]. Amylose content from this study was reduced and this might be due to processing method as proved by Elmsthl [28]; Moorthy [29]; Niba [30] and Adebayo [31].

The result showed in Table 4 also summarizes the β-carotene and phenolic compounds of the analyzed pre-gelatinized corm samples. The higher β-carotene (mg/100 g) (2.307 ± 0.162) was detected in taro boloso-1 pre-gelatinized flour with peel and followed by lower β-carotene (2.107 ± 0.502) in local taro pre-gelatinized flour with peel. However, the β-carotenes in this study were not differ significantly (p<0.05). In other words, β-carotene content decreased slightly in pre-gelatinized corms without peel and this may be due to breakdown of carotene contents during thermal processing and loss of some amount of β-carotene with peeling before cooking [32-34]. Therefore, flour samples pre-gelatinized with peel held good β-carotene content than that of flour samples pre-gelatinized without peel according to the result provided from this study. Concerning the phenolic compound composition, it was different significantly (p<0.05) among the varieties and processing methods of taro corm. The total phenolic compound (mg/100 g) in this study was highest for samples pre-gelatinized with peel and ranged from 8.3163 ± 2.165 to 6.921 ± 2.259. This might be due to the presence of phenolic groups in the peel increased the total phenols in the analyzed samples which was pre-gelatinized with peel in both varieties.

Macro and micro minerals

The mg/100 g values in DM basis of five major minerals were presented in Table 4. The Na content (mg/100 g) in this study was ranged from 9.716 ± 4.523 to 13.443 ± 5.704 and differs significantly (p<0.05). Higher Na value (mg/100 g) was obtained from boloso-1 taro pre-gelatinized without peel and pre-gelatinized with peel while the smaller value obtained from local taro pre-gelatinized without peel and pre-gelatinized with peel, respectively. From the result showed in the present study that the higher Na content might be due to the difference in taro varieties. The notable findings obtained were in consistent with the report of Umar et al. [35] who conducted a research on proximate and mineral contents of root crops. From the results accordingly, this study promotes that pre-gelatinization without peel in root crops may be a good way of reducing Na level from food samples and recommended for human consumption as noted as well by Gordon [36] and Baruah [37].

From the findings of the present study, the analyzed K content (mg/100 g) of the pre-gelatinized taro flour samples was presented in Table 4. Based on the findings the K content (mg/100 g) was differ significantly (p0.05) and ranged from17.743 ± 1.364 to 18.923 ± 1.543. The results found from this study predicted that local taro pre-gelatinized without peel samples had high K (mg/100 g) concentration than boloso-1 taro pre-gelatinized without peel and pre-gelatinized with peel. Potassium (K) mg/100 g is two times higher than that of Na mg/100 g in the analyzed taro flour samples (Table 4). According to Nijoku and Ohia [21] and Huang et al. greater (amount?) K mg/100 g concentration compared with lower (how much?) Na mg/100 g level is recommended for healthy diets and this could be taro as high K: Na food. Other minerals are also found abundantly in taro which includes magnesium, phosphorus and calcium [7,38]. A 1-cup serving of cooked taro contains 639 mg of K. when taro was included as part of a healthy diet and the food becomes high in K and can help to control blood pressure [2].

The Mg content (mg/100 g) of local taro and boloso-1 taro varieties of the corm in the present study was ranged from 8.233 ± 0.830 to 7.683 ± 0.185 and it differs significantly (p<0.05) between the varieties and the processing method?. The general trend observed from this study was local taro flour samples obtained greater Mg concentration than boloso-1 taro flour samples. In other words, local taro pre-gelatinized without peel composed the highest mg/100 g of Mg followed by taro pre-gelatinized without peel. As information provided from previous studies, thermal processing would increase the mineral composition and reduce anti-nutritional factors in different food samples. Therefore, the present study is consistent with noted studies and the notable finding from the study suggests pre-gelatinization could be appropriate method for reducing toxic compound. Therefore measuring Mg level in taro and other food crops is important because magnesium is needed for bone, immune health, muscle and nerve function. It also keeps blood pressure normal and regulates blood sugar in the body. Adult men need 400 to 420 mg of magnesium a day and adult women need 310 to 320 mg a day. One serving of taro meets 10 percent of the daily value for magnesium [2].

The P (mg/100 g) content in this study was ranged from 1.063 ± 0.307 to 0.736 ± 0.307 and it was not differ significantly (p>.05). The result provided from the present study showed flour pre-gelatinized with peel prevailed greater mg/100 g of P concentration than that of flour pre-gelatinized without peel (Table 4). Previous studies also provided evidence that the mineral contents of food samples might be increased due to the additional minerals found in the peel to the products. Therefore, the present study was in agreement with previous studies and the finding from the study suggests that the pre-gelatinization with peel was good as ways of improving the mineral content of taro [39,40].

As can be seen in from Table 4 of this study, the mg/100 g of Ca was ranged from 16.280 ± 4.680 to 11.280 ± 4.780 for boloso-1 flour pre-gelatinized without peel and for local flour pre-gelatinized without peel, respectively. The Ca (mg/100 g) contents differ significantly (p<0.05) and the result provided from the present study showed that the pre-gelatinized flour without peel composed the highest (16.280 ± 4.680 mg/100 g) of Ca concentration than that of pre-gelatinized flour with peel (11.280 ± 4.780 mg/100 g, respectively) in both varieties (Table 4). The Ca concentration was increased in processed taro corms due to pre-gelatinization effect and simultaneously reduced anti-nutritional constituents such as oxalate in taro that inhibit the bioavailability of Ca according to [41].

Regarding to micro mineral content of analyzed pre-gelatinized taro samples, the Fe (mg/100 g) in this study was ranged from 88.773 ± 17.205 to 104.303 ± 16.109, Zn (mg/100 g) from 8.526 ± 2.418 to 11.310 ± 2.674 and Cu (mg/100 g) from 0.296 ± .125 to 0.403 ± 0.096. The Fe (mg/100 g) content differ significantly (p<0.05). The results showed that pre-gelatinized flour without peel has greater Fe and Zn content than that of pre-gelatinized flour with peel in both taro varieties. These reductions of Fe and Zn content in pre-gelatinized flour with peel samples might be due to the binding interaction with anti-nutritional compounds [6,42-44]. However, in case of pre-gelatinization without peel provided that reduced anti-nutritional factors dominantly found in the peel. The findings of this study were in agreement with the work of Kordylas [45]; Ndimantang et al. Lima et al. and Lewu [38]. In contrary, Cu content was reduced slightly in samples pre-gelatinized without peel; hence Cu seems to have a dramatic reduction character during peeling and washing as noted by Charles, et al. [46].

Tannin, phytate, mucilage and oxalate content

The tannin (mg/100 g) in this study was ranged from 243.605 ± 175.874 to 353.772 ± 168.270 and differ significantly (p<0.05). The greater tannin (mg/100 g) obtained in local taro and while the smaller tannin content was found from boloso-1 variety subjected to pre-gelatinization without and with peel, respectively (Table 5). Great reduction of tannin content in boloso-1 samples was exhibited and this might be due to variety difference and the processing effect that might be reduced the concentration of the condensed tannin [47]. According to Prajapati et al. [48], condensed tannin, phytic acid, mucilage and oxalic acid concentrations in food samples could be reduced during washing, peeling, boiling and thermal processing [49]. Thus, based on the findings obtained from this study most of samples contained low tannin concentration when subjected to peeling and heating as reported [50]. The phytate (mg/100 g) content in this study was ranged from 0.923 ± 0.076 to 1.710 ± 1.320. (Table 6) and were not differ significantly (p>0.05). Lewu et al. [38] suggested that food processing such as washing, peeling, cooking, oven drying and milling could reduce or eliminated the level of phytic acid. Thus, based on the findings obtained from this study most of samples contained low phytic acid concentration when subjected to peeling and pre-gelatinization [44]. The mucilage (mg/100 g) in this study was ranged from 0.493 ± 0.478 to 0.160 ± 0.124 (Table 6) and were not differ significantly (p>0.05). Local taro samples pre-gelatinized with peel obtained high mucilage mg/100 g content of all while low mucilage mg/100 g content was founded in boloso-1 taro samples pre-gelatinized without peel. Generally, reductions of mucilage content in pre-gelatinized samples without peel were observed and this reduction might be due to the leaching out of mucilage to the water which was used to soaking sliced samples [51]. The oxalate content (mg/100 g) in this study was ranged from 102.000 ± 6.000 to 88.000 ± 19.287and differ significantly (p<0.05). The present result was in agreement with the findings of Hang et al. [52]; Catherwood et al. and Hang and Binh [53] who noted that washing, peeling, ensiling and boiling were the most effective methods of reducing the soluble and total oxalate. Other investigations have been reported regarding to oxalate content of taro and the findings in this study were below the suggested level of (221.652 ± 2.0143 mg/100 g) [53]. Catherwood et al. reported 60.6% proportion of soluble oxalate in total oxalate content of raw corms. Proportion of soluble to insoluble oxalate in a food would influence the effectiveness of processing methods such as boiling, cooking, sun drying and baking because the ability of the oxalate to solubilise in solution and its heat susceptibility will influence

Treatments				
Taro varieties	**Gelatinization methods**	**Fe (mg/100 g)**	**Zn (mg/100 g)**	**Cu (mg/100 g)**
Boloso-1	PGF1	104.303 ± 16.109^{a}	11.310 ± 2.674^{a}	0.296 ± .125^{abc}
	PGF2	88.773 ± 17.205^{d}	9.723 ± 4.219^{c}	0.360 ± 0.168^{ab}
Local	PGF1	99.420 ± 24.144^{b}	10.270 ± 4.188^{b}	0.320 ± 0.160^{abc}
	PGF2	92.873 ± 23.823^{c}	8.526 ± 2.418^{d}	0.403 ± 0.096^{a}
Average mean		96.342	9.957	0.345
CV (%)		12.484	1.279	1.401
Significance level (A × B)		*	*	*

$^{a-d}$ Means within a column with different superscripts differ significantly (p<0.05); SD: standard deviation; CV: coefficient of variation; PGF1: pre-gelatinized without peel, PGF2:pre-gelatinized with peel, A: Variety and B: Gelatinization method.

Table 5: Interaction of variety by gelatinization methods on micro mineral contents of pre-gelatinized taro starch samples (%DM basis).

		Treatments			
Taro varieties	**Gelatinization methods**	**Tannin (mg/100 g)**	**Phytate (mg/100 g)**	**Mucilage (mg/100 g)**	**oxalate (mg/100 g)**
Boloso-1	PGF1	243.605 ± 175.874^{d}	0.923 ± 0.076^{bc}	0.160 ± 0.124^{ab}	88.000 ± 19.287^{cd}
	PGF2	247.034 ± 181.787^{c}	1.705 ± 1.325^{a}	0.457 ± 0.520^{a}	92.000 ± 22.715^{b}
Local	PGF1	342.425 ± 187.916^{b}	1.663 ± 1.359^{ab}	0.410 ± 0.548^{a}	90.000 ± 21.633^{c}
	PGF2	353.772 ± 168.270^{a}	1.710 ± 1.320^{a}	0.493 ± 0.478^{a}	102.000 ± 6.000^{a}
Average mean		296.7095	1.5005	0.3802	93
CV (%)		60.417	5.962	1.82	20.202
Significance level (A × B)		*	*	*	*

$^{a-d}$ Means within a column with different superscripts differ significantly (p<0.05); SD: standard deviation; CV: coefficient of variation; PGF1: pre-gelatinized without peel, PGF2:pre-gelatinized with peel, A: Variety and B: Gelatinization method.

Table 6: Interaction of variety by gelatinization methods on major anti-nutritional contents of pre-gelatinized taro starch samples (%DM basis).

		Treatments		
Taro Varieties	**Gelatinization methods**	**Alpha(α)-amylase (mg/100 g)**	**Protase inhibitor (mg/α100 g)**	**Lectin (mg/α100 g)**
Boloso-1	PGF1	0.908 ± 0.036^{ab}	0.008 ± 0.004^{ab}	0.006 ± 0.005^{ab}
	PGF2	0.935 ± 0.014^{a}	0.007 ± 0.002^{ab}	0.011 ± 0.007^{a}
Local	PGF1	0.912 ± 00.042^{a}	0.009 ± 0.004^{ab}	0.008 ± 0.008^{ab}
	PGF2	0.917 ± 0.044^{a}	0.010 ± 0.004^{a}	0.011 ± 0.007^{a}
Average mean		0.9185	0.0087	0.0095
CV (%)		0.377	0.074	0.571
Significance level (A x B)		*	*	*

Table 7: Interaction of variety by gelatinization methods on minor anti-nutritional contents of pre-gelatinized taro flour samples (%DM basis).

		Treatments				
Taro varieties	**Processing methods**	**[Phy]:[Na]**	**[Phy]:[K]**	**[Phy]:[Fe]**	**[Phy]:[Ca]**	**[Phy]:[Mg]**
Boloso-1	PGF1	0.252 ± 0.123^{a}	0.140 ± 0.066^{ab}	0.087 ± 0.020^{b}	0.218 ± 0.133^{ab}	0.193 ± 0.043^{ab}
	PGF2	0.208 ± 0.048^{ab}	0.155 ± 0.059^{a}	0.115 ± 0.046^{a}	0.251 ± 0.096^{a}	0.218 ± 0.055^{a}
Local	PGF1	0.275 ± 0.112^{a}	0.118 ± 0.029^{ab}	0.105 ± 0.051^{ab}	0.221 ± 0.119^{ab}	0.199 ± 0.053^{ab}
	PGF2	0.282 ± 0.102^{a}	0.158 ± 0.056^{a}	0.118 ± 0.042^{a}	0.261 ± 0.102^{a}	0.228 ± 0.039^{a}
Average mean		0.2545	0.143	0.106	0.112	0.21
CV (%)		0.02	0.164	0.00041	0.889	0.754
Significance level (A × B)		*	*	*	*	*

$^{a-d}$ Means within a column with different superscripts differ significantly (p<0.05); SD: standard deviation; CV: coefficient of variation; PGF1: pre-gelatinized without peel, PGF2:pre-gelatinized with peel, A: Variety and B: Gelatinization method.

Table 8: Interaction of variety by gelatinization methods on phytate mineral molar ratio of the analyzed samples of pre-gelatinized taro starch samples (%DM basis).

		Treatments				
Taro varieties	**Processing methods**	**[Phy]:[Zn]**	**[Phy]:[Cu]**	**[Phy]:[P]**	**Non [Phy]:[P]**	**[oxa]:[Ca]**
Boloso-1	PGF1	0.074 ± 0.019^{ab}	0.090 ± 0.043^{a}	0.018 ± 0.011^{ab}	21.532 ± 12.57^{a}	6.202 ± 2.865^{c}
	PGF2	0.098 ± 0.038^{a}	0.076 ± 0.020^{ab}	0.026 ± 0.016^{a}	20.820 ± 13.35^{ab}	10.143 ± 6.211^{a}
Local	PGF1	0.088 ± 0.043^{a}	0.102 ± 0.038^{a}	0.021 ± 0.017^{a}	19.724 ± 14.06^{b}	8.588 ± 6.989^{b}
	PGF2	0.099 ± 0.037^{a}	0.102 ± 0.038^{a}	0.029 ± 0.012^{a}	13.077 ± 2.732^{c}	10.326 ± 5.955^{a}
Average mean		0.09	0.0927	0.024	18.788	
CV (%)		0.766	4.395	3.111	3.766	
Significance level (A × B)		*	*	*	*	*

$^{a-d}$ Means within a column with different superscripts differ significantly (p<0.05); SD: standard deviation; CV: coefficient of variation; PGF1: pre-gelatinized without peel, PGF2:pre-gelatinized with peel, A: Variety and B: Gelatinization method.

Table 9: Interaction of variety by gelatinization methods on phytate and oxalate mineral molar ratio of the analyzed samples of pre-gelatinized taro starch samples (%DM basis).

the residual proportion [42,52]. The present study provided an over view of pre-gelatinization method to reduce most of the dominant anti-nutritionals in taro samples and most of taro samples contained low tannin, phytate, mucilage and oxalate content when subjected to peeling and gelatinization.

Lectin, α-amylase and protease inhibitors

As demonstrated in Table 7, the two way interaction effect between taro varieties and gelatinization methods on α-amylase, protease and lectin inhibitors effect of pre-gelatinized taro flour samples had no significant (p>0.05) effect on α-amylase, protease and lectin inhibitors content (mg/100 g). However, slight reduction in α-amylase; protease and lectin inhibitors were observed in flour samples pre-gelatinized without peel (Tables 8 and 9). The other thing observed from this study was boloso-1 taro had contained the lower α-amylase, protease and lectin inhibitors while the greater α-amylase, protease and lectin inhibitors was founded in local taro variety. This may be due to variety differences and abundance of inhibitory levels in the peel than in the inside corm [54]. Related findings also showed that inhibitory effects could be inactivated by effective raw material preparation and processing of food [54-59].

Conclusions

This study shows that effect of raw material preparation like washing; peeling, Deeping and pre-gelatinization processing had impact on improving the nutritional quality and reduce the anti-nutritional content of taro corm. Therefore, before taro can be eaten, all parts of the plant must be well cooked, in order to break down the anti-nutritionals found in the corm. Pre-gelatinization after peeling provided the highest CP, crude fat or ether extract (EE) and carbohydrate content than that of corm samples pre-gelatinized with peel. However, pre-gelatinization with peel had better mineral concentration than that of pre-gelatinization without peel. Therefore, this study focused on pre-gelatinization processing of taro corms and enhanced the nutritional composition and eliminated most of anti-nutritionals that limits maximum utilization of taro and impose serious neglecting in both rural and urban consumers.

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