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Effect of Indigenous Processing by Obu Manuvu on the Anti-nutrient and Nutrient Factors of Taro (*Colocasia esculenta*)

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Abstract

Anti-nutrient factors are secondary plant metabolites that can adversely affect the full utilization of nutrients in plant-based food products. However, the level of these anti-nutrients can be reduced by the application of various food processing methods. This study determined the effect of indigenous processing by the Obu Manuvu in Sitio Ladian, Marilog District, Davao City, Philippines on the anti-nutrient factors, proximate composition and mineral content of taro. The indigenous process involves soaking and boiling of taro, which is then stuffed in bamboo tubes to make 'linutlut na gabi.' The anti-nutrients analyzed in this study were tannin, cyanogenic glycoside and oxalate. Results showed a significant reduction amounting to 66.67, 98.08 and 91.74% for these anti-nutrients, respectively. The indigenous processing also showed a significant effect on the proximate composition of taro, specifically on the moisture (13.06% increase) and crude ash (2.45% increase) contents. For crude fat, crude fiber and crude protein contents, no significant changes were observed. For the mineral analyses, it was found that iron and manganese increased by 152.45 and 26.32%, respectively, after indigenous processing. Moreover, no significant changes were observed in the zinc and calcium contents of taro after indigenous processing. Hence, the processing method of the Obu Manuvu was effective in decreasing the anti-nutrient content, particularly tannin, cyanogenic glycoside and oxalate. This also improved the nutrient profile of taro as shown by the increase in iron and manganese. This study could be used for future dietary interventions to address issues of malnutrition and food safety.

***Keywords**:* anti-nutrients, indigenous processing, mineral content, proximate composition, taro

1. Introduction

Since the earliest times, farming and hunting were the primary means of acquiring food for the indigenous communities in the Philippines. Even so, cases of child malnutrition and deaths related to and resulting from lack of proper nutrition are still prominent in their communities. Prakash (2010) mentioned that malnutrition is caused by poor diet, diseases, food insecurity, unhygienic living conditions, inadequate health services and lack of information. At the same time, crops, such as taro contain anti-nutrients that reduce the nutritional quality of available food resources making it an important factor affecting malnutrition (Blossner and De Onis, 2005).

Anti-nutrients are compounds naturally produced in food or feedstuff through various mechanisms and are also known as secondary metabolites in plants proven to be biologically active (Gemede and Ratta, 2014). Certain plants produce anti-nutrients to boost their defense against insects, pathogens, or hostile growing conditions, but these anti-nutrients limit the maximum utilization of nutrients, specifically proteins, vitamins, and minerals, hence decreasing the overall nutritive value of plants (Tadele, 2015).

There are many anti-nutrients found in plants. Among these, tannin is the most abundant. It is a caustic, water-soluble and plant-polyphenolic compound that forms precipitates with proteins and other organic compounds including amino acids and alkaloids. It is also commonly found in many trees and shrub foliage, seeds and agricultural by-products. Another anti-nutrient, cyanogenic glycoside, is a derivative of amino acids which are present in more than 2,500 plant species (Vetter, 2000). It is usually found in economically important crops such as cassava, durian and white clover but further attracted great concerns and research attention due to the poisoning nature of hydrogen cyanide (Vetter, 2017). Oxalate is another anti-nutrient found in small amounts in cassava, beet, yam, spinach and taro (Savage *et al.*, 2002). Oxalate has no known health benefits to humans. Conversely, it reacts with calcium and forms insoluble calcium oxalates, thus reducing calcium absorption (Albihn and Savage, 2001).

The Obu Manuvu community resides in the districts of Baguio, Calinan and Marilog, Davao City, Philippines. Like other indigenous communities, they are also affected by the damaging effects of malnutrition. There are high cases of underweight and stunted children due to lack of access to nutritious foods, inadequate health services and the presence of anti-nutrient in plant foods

(Barba and Feliciano, 2002). Taro (*Colocasia esculenta*), an important constituent of the diet of the Obu Manuvu, provides a high amount of energy and is a good non-animal source of zinc. However, like any other plant food, it contains anti-nutrients (Bhandari and Kabawata, 2004).

Nevertheless, lowering anti-nutrient contents could be possible. Postharvest treatments such as boiling, roasting, dehulling and fermentation could significantly decrease the anti-nutrients (Singh and Mohanty, 2015). Thus, knowledge regarding indigenous food processing done by the Obu Manuvu community can be a tool for addressing the current issues in food safety and malnutrition (Aberoumand, 2011).

The primary goal of this research was to determine the effects of an indigenous food processing method as done by the Obu Manuvu community in Sitio Ladian, Marilog District, Davao City on the levels of anti-nutrient and nutrient factors in taro. Specifically, it aimed to document the process and determine the proximate composition, anti-nutrient and mineral content before and after processing.

2. Methodology

2.1 Sample Collection and Preparation

Prior to the conduct of the research, a written permission was duly secured from the National Commission on Indigenous Peoples (NCIP), as well as from the chieftain of the Obu Manuvu community. The people involved, especially in the food preparation and processing, were given free, prior and informed consent (FPIC) all throughout the duration of the study.

Raw and processed taro samples were collected from the Obu Manuvu community using resealable plastic bags and placed inside an icebox. Taro samples were freeze-dried, ground and stored for mineral and anti-nutrient analyses. For proximate analysis, taro samples were not freeze-dried but were stored in sealed plastic bags inside the refrigerator (RS62R5031M9, Samsung, South Korea) (4 °C) immediately after collection.

2.2 Chemical Analyses

Both raw and processed taro samples were analyzed for their anti-nutrient, proximate composition and mineral content. Proximate analyses include moisture, crude fat, crude ash, crude protein, crude fiber and total carbohydrate contents. Anti-nutrients that were analyzed were tannin, cyanogenic glycoside and oxalate. On the other hand, iron, zinc, calcium and manganese were analyzed for mineral analysis.

2.2.1 Anti-nutrient Analysis

Tannin

Tannin analysis was done using the method employed by Mohammed and Manan (2014) with some modifications. Sample preparation was done by adding 1 g of freeze-dried taro to 25 mL of 85% methanol (reagent-grade) (Scharlau, United States). The mixture was then incubated in a water bath at 60 °C for 1 h. It was then centrifuged at 7,000 rpm for 5 min at 4 °C using Senova refrigerated centrifuge (NovaFuge B115-20R, Senova, China). After which, the supernatant liquid was collected. Folin-Ciocalteu assay was used to quantify the total tannin content following the method of Tamilselvi *et al.* (2012). Gallic acid (reagent-grade) (Spectrum Chemical, United States) was then utilized to prepare the standard solutions in varying concentrations (0.001, 0.005, 0.01, 0.05 and 0.2 mg/mL). In a 10-mL volumetric flask, 100 µL of the sample extract was added with 750 µL of distilled water, 500 µL of 0.5 N Folin-Ciocalteu reagent (reagent-grade) (Sigma-Aldrich, United States) and 1,000 µL 35% sodium carbonate (reagent-grade) (HiMedia, United States). It was then diluted to the 10-mL mark with distilled water and was vigorously mixed. After this, it was incubated for 30 min. The absorbance of the sample was then read at 725 nm using a spectrophotometer (UV-Vis 1700, Shimadzu, Japan). Similar steps were followed for the blank and standard solutions. The following linear regression model was used to obtain the equation of the straight line (Equation 1).

$$y = mx + b \tag{1}$$

where y = absorbance of the sample solution, m = slope of the line, x = concentration of tannin in the sample and b = y-intercept. The amount of tannin is expressed in terms of percentage by weight.

Cyanogenic Glycoside

Cyanogenic glycoside content determination was performed using the alkaline picrate method by Eleazu and Eleazu (2012). The preparation of standard solutions was done by diluting potassium cyanide (KCN) (analytical-grade) (Univar, United States) in distilled water followed by acidification of the solution using 37% HCl (reagent-grade) (ACI Labscan Limited, United States). Standard solutions were 0.005, 0.01, 0.05, 0.1 and 2 mg/mL. The sample was prepared by dissolving 1 g in 25 mL of distilled water. It was then allowed to stand overnight. After 12 h, the sample was filtered and the filtrate was used for the cyanide content determination. A total of 1 mL of the filtrate was added with 4 mL of alkaline picrate. The latter was prepared by dissolving 1 g of picric acid (reagent-grade) (Sigma-Aldrich, United States) and 5 g of Na_2CO_3 (reagent-grade) (HiMedia, United States) in 200-mL distilled water. It was then incubated at 50 °C in a water bath for 5 min. Absorbance was measured using the spectrophotometer at 490 nm. Similar steps were followed for the blank and standard solutions. For the linear regression, x in Equation 1 now represents the concentration of cyanogenic glycoside in the sample. The amount of cyanogenic glycoside in the sample was expressed in terms of percentage by weight.

Oxalate

Oxalate was analyzed by titration following the method of Hailu and Addis (2016). A total of 2 g of the sample were placed in a 250-mL Erlenmeyer flask containing 190 mL of distilled water. A total of 10 mL of 6 M HCl (reagent-grade) (ACI Labscan Limited, United States) solution were then added and the sample was digested for an hour at 100 °C. After which, it was cooled and filled up to the 250-mL mark with distilled water. Four drops of methyl red indicator (reagent-grade) (Merck, Germany) were added, followed by the dropwise addition of concentrated NH_4OH (reagent-grade) (Sigma-Aldrich, United States) until the color of the solution changed from pink to yellow. The mixture was then heated to 90 °C and subsequently cooled and filtered. The filtrate was heated again to 90 °C and a 5% $CaCl_2$ (reagent-grade) (Spectrum Chemical, United States) solution was added with constant stirring. Therefter, the solution was cooled and stored overnight. After this, the solution was centrifuged at 2,500 rpm for 5 min using a refrigerated centrifuge to separate the supernatant liquid from the precipitate. The precipitate was then completely dissolved in 20 mL of 20% H_2SO_4 (reagent-grade) (Scharlau, United States), and the volume of the solution was filled up to 200 mL by adding distilled water. The solution was heated to near boiling and titrated with standard 0.1027 N $KMnO_4$ (reagent-grade) (Univar, United States) solution until a pink color persisted for 30 seconds. Analyses were done in triplicates. The oxalate content was calculated using Equations 2-4.

$$Equivalence\ of\ KMnO_4 = equivalence\ of\ C_2O_4^{-2} \tag{2}$$

$$Mass\ of\ oxalate = (N\ of\ KMnO_4)(volume\ in\ liter\ of\ KMnO_4)\ \left(\frac{MM\ of\ C_2O_4^{-2}}{n}\right) \tag{3}$$

where N = normality, MM = molar mass and n = number of equivalents of $C_2O_4^{-2}$.

$$\%\ oxalate = \frac{g\ oxalate}{g\ sample} \times 100 \tag{4}$$

2.2.2 Proximate Composition

The procedures used in determining the proximate composition of the samples were according to the standard methods of the Association of Official Analytical Chemists (AOAC) (1990). After chopping the taro samples into fine pieces, proximate analysis was conducted (moisture content: AOAC Method 925.10 [air-oven method]; crude ash: AOAC Method 923.09 [incineration]; crude fat: AOAC Method 920.399 [Soxhlet method]; crude fiber: AOAC Method 984.04 [Wendee method]; and crude protein: Kjeldahl method.) The total carbohydrate was obtained by computing the difference between 100% and the sum of percent moisture, crude ash, crude fat, crude fiber and crude protein. A third-party laboratory conducted all the analyses.

2.2.3 Mineral Content

A third-party laboratory performed both the sample preparation and the analyses of mineral content (iron, zinc, calcium and manganese) using Atomic Absorption Spectrophotometry (AAS) (AA-6300, Shimadzu, Japan).

2.3 Statistical Analysis

The means of the data obtained for the two unrelated groups, raw and processed taro, were compared using an independent *t*-Test at a 5% level of significance using GNU PSPP version 1.2.0-g0fb4db (GNU Project, 2019). All analyses were done in three trials with each trial having three replicates.

3. Results and Discussion

3.1 Indigenous Processing of Taro by Obu Manuvu

The Obu Manuvu community practices numerous indigenous processing of food passed down through generations. One product of indigenous processing of the Obu Manuvu using locally-grown taro is the *linutlut na gabi*.

Figure 1 shows the indigenous processing of taro to prepare *linutlut na gabi*. Taros were peeled using a knife, sliced into small pieces (about 6-7 cm^3), then washed and soaked in water for 5-10 min to avoid undesirable browning. Sliced taros were stuffed into clean bamboo tubes, approximately a foot long. The bamboo tubes were then filled with water and covered with banana leaves. It was heated over an open flame for 20-30 min or as soon as the bamboo tubes turned dark in color. The tubes were then cut lengthwise to facilitate easier removal of the cooked product. *Linutlut na gabi* is routinely served as snack food among the Obu Manuvu community.

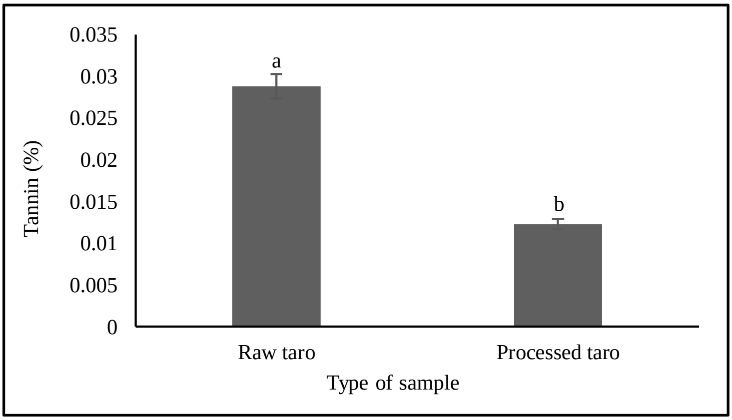
Figure 1. Indigenous processing of *linutlut na gabi*: raw taro was prepared for peeling (a), sliced taro was soaked in water after peeling (b), soaked taro was stuffed into a bamboo tube and covered with banana leaves (c), bamboo tube was heated in an open flame (d), burnt outer layer of the bamboo tube was removed (e) and bamboo tube was cut to remove the cooked taro (f).

3.2 Anti-nutrient Contents

According to Bhandari and Kabawata (2004), taro contains numerous anti-nutrients that can affect the nutritional quality of the food. The results of the anti-nutrient analyses of raw and processed taro are as follows:

3.2.1 Tannin

Figure 2 shows the effect of the indigenous processing by the Obu Manuvu on the tannin content of taro. From 0.03±0.00 to 0.01±0.00%, a significant decrease ($p \leq 0.05$) in tannin content was noted amounting to 66.67%. The observed decrease in tannin agrees well with the study of Olajide *et al.* (2011), who found that the tannin content of taro decreased by 69.23% after boiling. Other researchers also obtained similar results after soaking and boiling taro (Onu and Madubuike, 2006; Adane *et al.*, 2013; Azene and Molla, 2017).



Bars with different letters indicate a significant difference at α = 0.05.

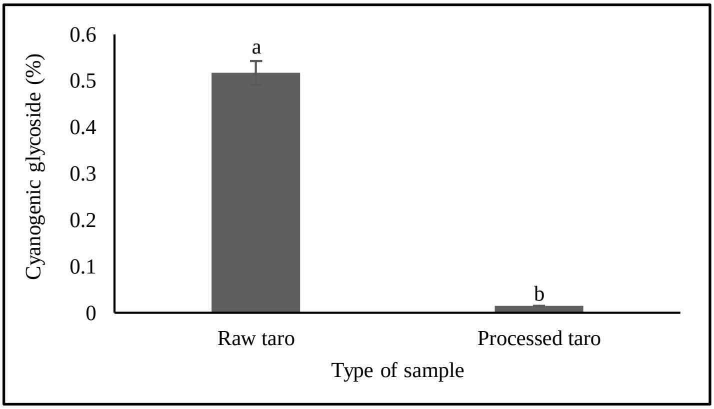
Figure 2. Effect of indigenous processing on the tannin content of raw and processed taro

Foods with a high amount of tannin are considered to have low nutritional quality because tannins can precipitate proteins such as digestive enzymes by forming complexes resulting in lesser bioavailability of proteins. In this study, boiling caused the decrease in taro's tannin content since boiling water leaches out hydrolyzable tannins (Adane *et al.*, 2013). In the study by Nwaogu and Udebuani (2010), it was indicated that an increase in temperature causes the tannin-protein complex to break down. This increases the digestibility and palatability of plant-based food. Furthermore, the study of Olajide *et al.* (2011) revealed that soaking also leads to tannin reduction due to leaching out.

The total acceptable intake of tannin for adults is 560 mg/day (Akalu and Geleta, 2017). The serving size of 100 g of *linutlut na gabi* contains 10 mg of tannin. Since the tannin content of processed taro was within the acceptable limit, it imparts no associated significant health hazard if consumed in minimal amounts. Thus, the Obu Manuvu group practices an effective indigenous processing technique in reducing the tannin content in taro through *linutlut na gabi*.

3.2.2 Cyanogenic Glycoside

Figure 3 shows the effect of indigenous processing on the cyanogenic glycoside content of taro. A significant decrease ($p \leq 0.05$) from 0.52±0.02 to 0.01±0.00% (98.08% reduction) was observed after processing.



Bars with different letters indicate a significant difference at $\alpha = 0.05$.

Figure 3. Effect of indigenous processing on the cyanogenic glycoside content of raw and processed taro

Cyanogenic glycosides yield hydrogen cyanide which is a food toxin. Cyanide is produced when triglochinin (the cyanogenic glycoside in taro) breaks down in the presence of the β-glucosidase enzyme (Hösel and Nahrstedt, 1975). This toxin affects the nervous system and leads to retrobulbar neuritis, optic atrophy coupled with pernicious anemia and thyroid effects such as goiter and cretinism (Ernesto *et al.*, 2002). High concentrations of cyanogenic glycoside result in higher concentrations of hydrogen cyanide (Codex Alimentarius Commission, 2013).

A significant decrease in the cyanogenic glycoside content of boiled root crops was also observed in wild cocoyam and taro corms (Olajide *et al.*, 2011), African yam bean (Ndidi *et al.*, 2014) and cassava (Bolarinwa *et al.*, 2016). Boiling reduces the anti-nutrients from plant-based foods. During boiling, plant cell walls break causing leakage of anti-nutrients and other toxic substances (Ogbadoyi *et al.*, 2006). Montagnac *et al.* (2009) pointed out that boiling time and the water levels used for boiling affect the reduction of cyanogenic glycosides. Rawat *et al.* (2015) also observed a 77 and 87% reduction in cyanogenic glycoside contents of bamboo shoots after 10 and 20 min of boiling, respectively.

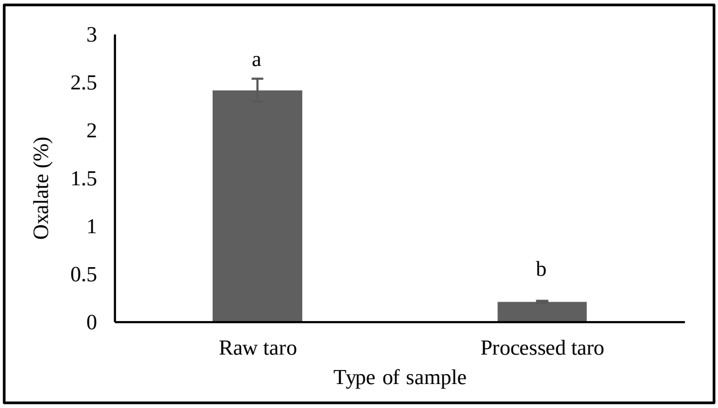
Moreover, Oke (1994) stated that the reduction of cyanogenic glycoside content through boiling is more efficient if cassavas are cut into small sizes and boiled in a large volume of water. Particle size reduction facilitates the faster breakdown of cyanogenic glycoside into a volatile hydrogen cyanide gas (Cardoso *et al.*, 2005; Ivanov *et al.*, 2012).

The total acceptable intake of cyanogenic glycosides for adults is 0.5 to 3.5 mg/kg body weight/day (Bolarinwa *et al.*, 2016). Hence, for a 50-kg adult, the acceptable amount for cyanogenic glycoside is 25 to 175 mg per day. The serving size of 100 g of *linutlut na gabi* contained 10 mg of cyanogenic glycoside. Cyanogenic glycoside in processed taro was found to be within the acceptable limit and, thus, poses no associated significant health hazard if 100 g of processed taro is consumed per day. Therefore, the indigenous processing technique of the Obu Manuvu was effective in reducing cyanogenic glycoside in taro.

3.2.3 Oxalate

Oxalates are major anti-nutrients present in taro, thereby limiting its full utilization (Food and Agriculture Organization [FAO], 1990). Oxalates impart harmful effects on human health and nutrition by decreasing the absorption of calcium and facilitating the formation of kidney stones (Noonan and Savage, 1999). The indigenous processing done by Obu Manuvu resulted in a significant decrease in oxalate ($p \leq 0.05$) amounting to 91.74% as shown in Figure 4.

The Obu Manuvu's indigenous preparation of taro employed washing, soaking and boiling. This caused a significant decrease in the oxalate content. Adane *et al.* (2013) obtained a similar result and reported a 70.9% reduction in the oxalate content of taro after boiling. Furthermore, other studies also showed a decrease in the oxalate content of taro after washing, soaking and boiling (Iwuoha and Kalu, 1994; Huang *et al.*, 2007; Olajide *et al.*, 2011; Azene and Molla, 2017). Albihn and Savage (2001) further noted that boiling can cause cell rupture and leakage of soluble oxalates into the cooking water. Aside from these, the slicing of taro is also a crucial step in cooking *linutlut na gabi*, which could have contributed to the decrease in oxalate content. The study of Buntha *et al.* (2008) affirmed this and mentioned that peeling and grating taro could reduce its acridity because of oxalates. Shanthakumari *et al.* (2008) explained that size reduction increases the surface area of wild yams to the soaking medium, thus facilitating the leaching of oxalates.



Bars with different letters indicate a significant difference at $\alpha = 0.05$.

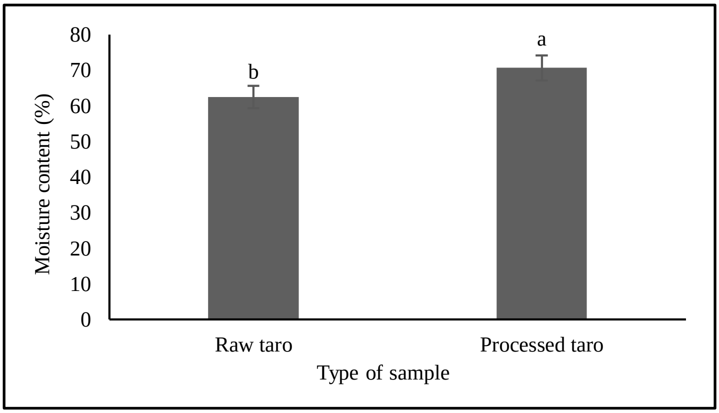
Figure 4. Effect of indigenous processing on the oxalate content of raw and processed taro

The total acceptable daily intake of oxalates should not exceed 15 to 30 g/day (Silberhorn, 2005). Thus, 100 g of *linutlut na gabi* has 0.210 g of oxalate, which is lower than the acceptable amount. Hence, the indigenous processing technique of the Obu Manuvu was effective in reducing the oxalate content in taro making it safe for human consumption.

3.3 Proximate Analysis Results

3.3.1 Moisture

The effect of the indigenous processing done by the Obu Manuvu on the moisture content of taro is shown in Figure 5. There was a significant increase in moisture ($p \leq 0.05$) by 13.06% after processing. Adane *et al.* (2013) and Azene and Molla (2017) showed similar findings wherein the moisture content of taro also increased after boiling. This is due to moisture absorption of the fibers and other natural biochemical components of the plant food material during boiling (Alcantara *et al.*, 2013). An increase in moisture content after processing was also observed in other crops such as African yam beans, *Moringa oleifera* seeds, *Solanum nigrum*, *Senecio biafrae* and local groundnuts (Lola, 2009; Mada *et al.*, 2012; Mbah *et al.*, 2012; Ndidi *et al.*, 2014).



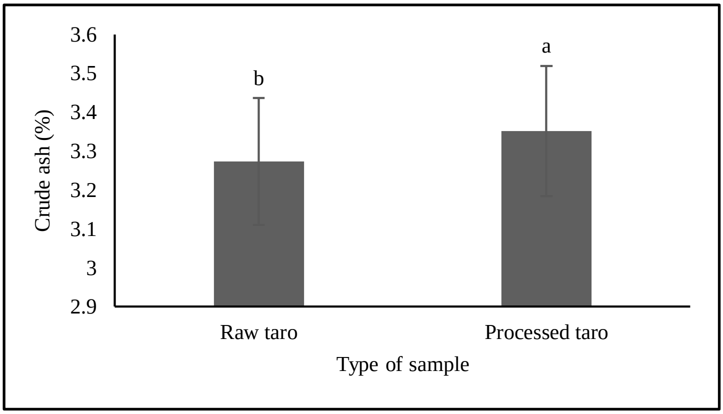
Bars with the same letters indicate a significant difference at $\alpha = 0.05$.

Figure 5. Effect of indigenous processing on the moisture content of raw and processed taro

The increase in moisture content after indigenous processing of taro can profoundly affect its shelf-life and safety if not stored properly or consumed immediately. Foods with high moisture content are more susceptible to microbial growth; hence, proper storage of processed taro must be observed by the Obu Manuvu community.

3.3.2 Crude Ash

Indigenous processing caused a significant increase ($p \leq 0.05$) from 3.27±0.06 to 3.35±0.03% as shown in Figure 6. This is equivalent to a 2.45% increase in the total minerals present. This may be due to the observed decrease in anti-nutrients, specifically tannins and oxalate as these can bind minerals in the food sample rendering them unavailable. This is consistent with the findings of Nwafor *et al.* (2017) wherein the crude ash content of *Adenanthera pavonina* seeds increased from 4.03±0.019 to 4.25±0.01% after boiling. Thus, the indigenous processing of taro by the Obu Manuvu was effective in enhancing its mineral content.

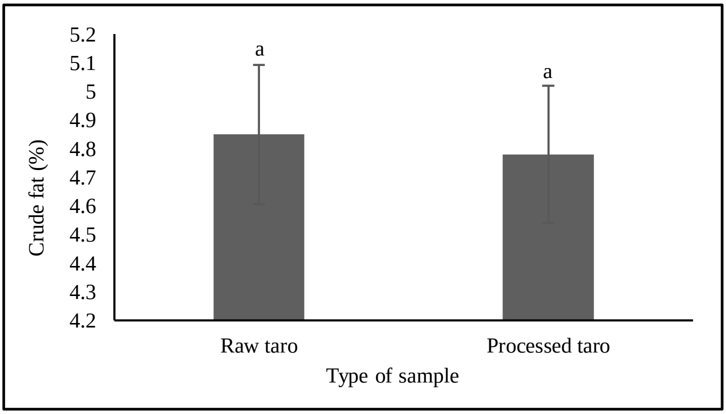


Bars with different letters indicate a significant difference at α = 0.05.

Figure 6. Effect of indigenous processing on the crude ash content of raw and processed taro

3.3.3 Crude Fat

Figure 7 depicts the effect of the indigenous processing done by the Obu Manuvu on the crude fat content of taro. Indigenous processing did not exhibit a significant difference in its crude fat compared with the raw taro. Similar results were obtained for boiled lentils (Hefnawy, 2011) and two non-conventional vegetables (Lola, 2009). However, the studies of Alcantara *et al.* (2013) and Azene and Molla (2017) found a significant reduction in the crude fat content of taro after boiling.



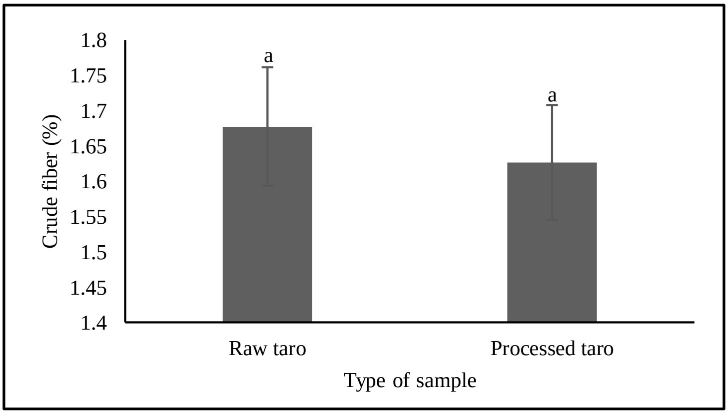
Bars with different letters indicate a significant difference at α = 0.05.

Figure 7. Effect of indigenous preparation on the crude fat content of raw and processed taro

The process of boiling can cause a reduction in the crude fat content due to the melting of fat granules (Lola, 2009). In this study, the heating process might not be long enough to alter the fat granules of taro resulting in no significant changes in the fat content (Amon *et al.*, 2011).

3.3.4 Crude Fiber

The crude fiber content of the taro samples before and after indigenous processing by the Obu Manuvu showed no significant difference as reflected in Figure 8. The obtained crude fiber values of 1.67±0.14% in raw taro and 1.63±0.11% in processed taro were comparable to that of wild cocoyams (Olajide *et al.*, 2011). In contrast, Alcantara *et al.* (2013) and Azene and Molla (2017) showed a significant decrease in the crude fiber content of taro after boiling. This is because an increase in temperature causes the breakage of weak bonds of polysaccharide chains and glycosidic linkages within the dietary fiber polysaccharides (Lola, 2009). However, in the indigenous processing of taro, the heat application upon boiling may not be sufficient to cause a significant change in the crude fiber content of processed taro.



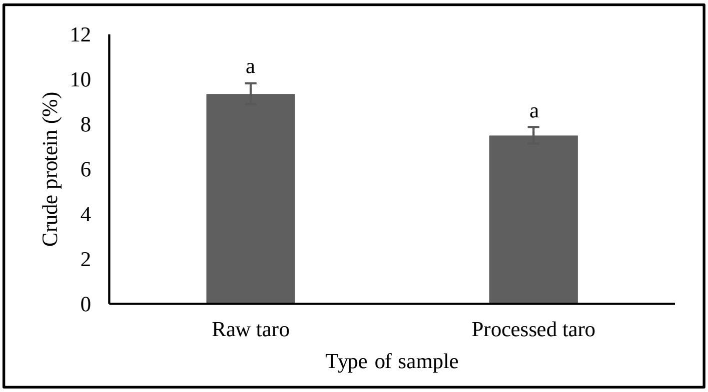
Bars with the same letters indicate a significant difference at $\alpha = 0.05$.

Figure 8. Effect of indigenous processing on the crude fiber content of raw and processed taro

3.3.5 Crude Protein

The effect of the indigenous processing done by the Obu Manuvu group on the crude protein content of taro is presented in Figure 9. It shows that the crude protein content did not significantly differ after processing. This contrasts with the findings from other studies wherein the crude protein content of taro significantly decreased after boiling (Onyeike and Oguike, 2003; Adane *et al*., 2013; Alcantara *et al*., 2013; Azene and Molla, 2017).

Olajide *et al.* (2011) explained that the decrease in crude protein after boiling could be due to protein denaturation wherein heat breaks the hydrogen bonds and non-polar hydrophobic interactions of the secondary and tertiary structures of proteins. FAO (1990) also suggests that it could be attributed to the leaching out of soluble amino acids. Tadele (2015), on the other hand, reported that tannin could form complexes with protein resulting in decreased availability of the latter. Thus, if the tannin level decreases, the protein content is expected to increase. However, in this study, the crude protein content did not significantly change after indigenous processing even though there was a significant decrease in the tannin content of processed taro.



Bars with the same letters indicate a significant difference at $\alpha = 0.05$.

Figure 9. Effect of indigenous processing on the crude protein content of raw and processed taro

The recommended dietary allowance (RDA) for protein for children ranges from 17-72 g and 62-71 g for adults (Food and Nutrition Research Institute [FNRI], 2015). The protein contents of raw and processed taro, which amounted to 9.35 g/100 and 7.50 g/100 g, respectively, were below the RDA. This is indeed a nutritional concern since protein deficiency may likely lead to kwashiorkor, marasmus, impaired mental health, edema, weak immune system, wasting and shrinkage of muscle tissues (Khan *et al*., 2017). The Obu Manuvu must not solely depend on taro for dietary protein requirements. Thus, high-protein foods should be supplemented to meet the RDA for protein for both children and adults.

3.3.6 Total Carbohydrates

The effect of the indigenous processing on the total carbohydrates of taro is shown in Figure 10. The total carbohydrates decreased from 18.36 to 12.09%. This is equivalent to a 34.16% reduction in the total carbohydrate content. Carbohydrates serve as a storage form of energy. Hence, the indigenous process employed by the Obu Manuvu was associated with the lowering of the energy content of processed taro. This could have serious repercussions among the Obu Manuvu community as taro is considered a staple food. The total carbohydrate content of taro varies depending on the cultivar, climate and soil type (Nip *et al.*, 1989).

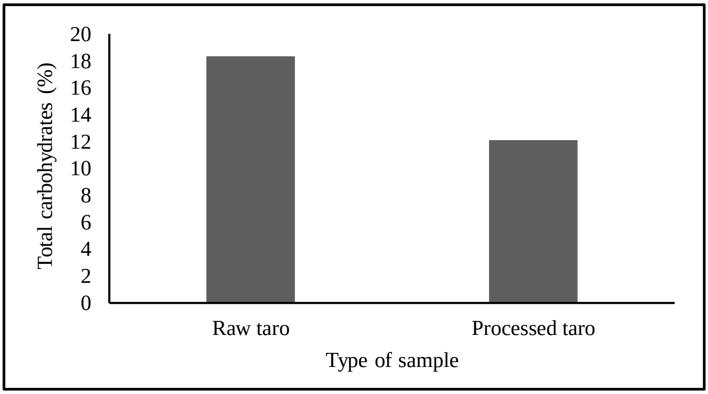


Figure 10. Effect of indigenous processing on the total carbohydrate content of raw and processed taro

Table 1 summarizes the proximate composition of raw and processed taro. Overall, the indigenous processing of taro by the Obu Manuvu significantly affected only its moisture and crude ash contents.

Table 1. Proximate composition of raw and processed taro

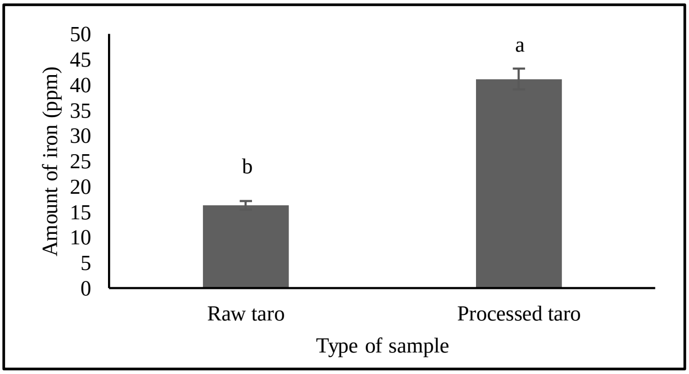
Composition (%)	Raw taro	Processed taro
Moisture content	$62.49+1.77^{b}$	$70.65+2.30^{a}$
Crude ash	$3.27+0.06^{b}$	$3.35+0.03^{a}$
Crude fat	$4.85+0.16^{a}$	$4.78+0.17^{a}$
Crude fiber	$1.68+0.14^{a}$	$1.63+0.11^{a}$
Crude protein	$9.40+1.77^{a}$	$7.50+0.85^{a}$
Total carbohydrates	18.31	12.09

Values represent mean +SD. In a row, values with different letter superscripts denote statistical difference (α = 0.05).

3.4 Mineral Contents

3.4.1 Iron

Iron is a mineral essential in producing hemoglobin – a protein found in red blood cells responsible for oxygen transport in the body. Iron is also important in maintaining a healthy immune system. Lack of iron may cause tiredness and anemia (Scrimshaw, 1990). The iron content of taro significantly increased ($p \leq 0.05$) from 16.30±0.14 to 41.15±0.07 ppm after being subjected to the indigenous processing as shown in Figure 11. This was equivalent to a 152.45% increase in iron content. Alcantara *et al.* (2013) also reported an increase in the iron content of taro powder and cookies, which underwent soaking and boiling. The same results were obtained from taro corms (Adane *et al.*, 2013), taro leaves (Lewu *et al.*, 2009) and *A. pavonina* seeds (Nwafor *et al.*, 2017) after boiling.



Bars with different letters indicate a significant difference at $\alpha = 0.05$.

Figure 11. Effect of indigenous processing on the iron content of raw and processed taro

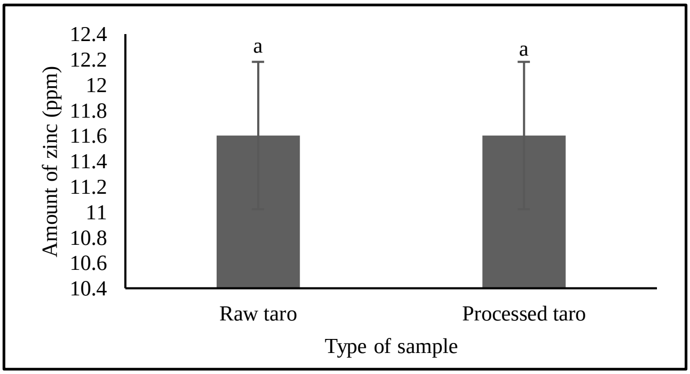
Tadele (2015) reported that there is a negative correlation between tannin and iron. Thus, the significant decrease in tannin content observed in this study could be the reason for the significant increase in the iron content of processed taro. Furthermore, since iron is one of the minerals, an increase in iron content could also be associated with the observed increase in the crude ash content of the processed taro.

The RDA of iron is 8-28 mg/day for children and 10-28 mg/day for adults (FNRI, 2015). Consumption of 100-g processed taro allows one to get 4.11

mg of iron. Hence, it can be said that despite the increase in the iron content after processing, it was still insufficient to meet the RDA. Thus, consumption of other foods rich in iron is recommended.

3.4.2 Zinc

Zinc is essential in growth and development, immunity, neurological function, reproduction, cell division, wound healing and the breakdown of carbohydrates (Prasad, 1984). Figure 12 shows no significant change in the zinc content of taro after the processing. This contrasts with Alcantara *et al.* (2013) who found that the zinc content of taro powder, taro noodles and taro cookies changed significantly after soaking and boiling. Moreover, Nakitto *et al.* (2015) reported that a decrease in tannin content could cause an increase in zinc content. However, in this study, the decrease in tannin did not significantly affect the zinc content of taro.



Bars with the same letters indicate a significant difference at $\alpha = 0.05$.

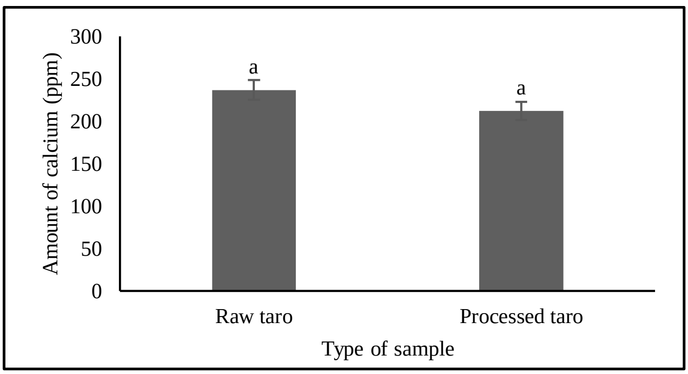
Figure 12. Effect of indigenous processing on the zinc content of raw and processed taro

The RDA of zinc is 4.0-9.2 mg/day for children and 4.6-6.5 mg/day for adults (FNRI, 2015). Consumption of 100 g of processed taro allows the intake of 1.16 mg of zinc. Thus, the zinc content of both raw and processed taro was lower than the RDA. Hence, supplementation of zinc-rich foods is recommended to the community.

3.4.3 Calcium

Calcium helps in building and maintaining strong bones and teeth. Sustained calcium intake can help prevent osteoporosis, which is indicative of thin and weak bones. Calcium also helps muscles work and aids in a proper heartbeat (Balk *et al.*, 2017).

As shown in Figure 13, the indigenous processing of taro by Obu Manuvu did not significantly affect its calcium content. This is in contrast with other studies on taro (Azene and Molla, 2017), taro noodles and cookies (Alcantara *et al.*, 2013), taro leaves (Lewu *et al.*, 2010) and cocoyam (Akpan and Umoh, 2004) wherein the calcium content significantly decreased after boiling. Azene and Molla (2017) explained that the calcium content slightly decreased due to leaching during boiling. On the other hand, for taro corms (Adane *et al.*, 2013) and taro powder (Alcantara *et al.*, 2013), the calcium content significantly increased after boiling, which correlated with the significant decrease in oxalate content observed in both studies. However, in this study, the decrease in oxalate and tannin did not significantly affect the calcium content of processed taro. This may be possible because the decrease in oxalate and tannin may not be sufficient to cause significant changes in the calcium content.



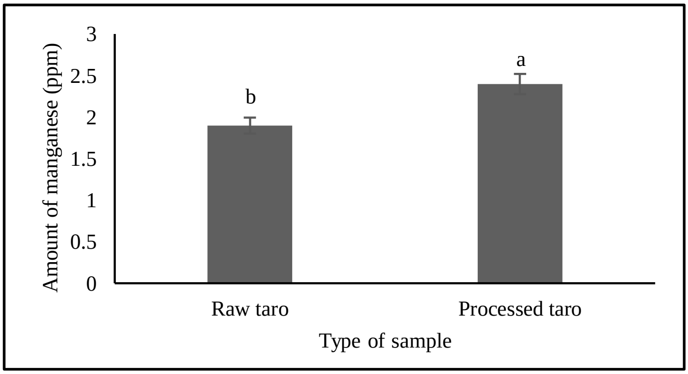
Bars with the same letters indicate a significant difference at $\alpha = 0.05$.

Figure 13. Effect of indigenous processing on the calcium content of raw and processed taro

The RDA of calcium is 500-1,000 mg/day for children and 750-800 mg/day for adults (FNRI, 2015). Consumption of 100 g of indigenous processed taro imparted only 21.25 mg of calcium; hence, taro was a poor source of calcium for the Obu Manuvu community. Thus, it is suggested to consume other calcium-rich foods.

3.4.4 Manganese

Figure 14 shows a significant increase ($p \leq 0.05$) in the manganese content of taro after indigenous processing by the Obu Manuvu. Manganese increased by 26.32% from 1.9±0.00 to 2.4±0.00 ppm. This is consistent with the findings of Bradbury and Holloway (1988). The increase in manganese could be attributed to the decrease in tannin as supported by the results of Klimis-Zacas (1993) validating an indirect relationship between manganese and tannin.



Bars with different letters indicate a significant difference at $\alpha = 0.05$.

Figure 14. Effect of indigenous processing on the manganese content of raw and processed taro

Manganese serves as a cofactor for many enzymes involved in metabolism. It is also important in digestion, reproduction, antioxidant defense, energy production, immune response and regulation of neuronal activities (Chen *et al.*, 2018).

The RDA of manganese is 0.003-1.5 mg/day for infants, 1.6-2.2 mg/day for children and 1.8-2.3 mg/day for adults (Ndidi *et al.*, 2014). Consumption of 100-g processed taro imparted only 0.24 mg of manganese, which was below the RDA for adults. Hence, although manganese in taro significantly increased after processing, it was still below the RDA. The Obu Manuvu must consider supplementation of foods rich in manganese.

4. Conclusion and Recommendation

The study determined the effect of indigenous processing of taro by the Obu Manuvu on its nutritional and anti-nutritional content. Indigenous processing involved the cooking of taro stuffed in bamboo tubes. Chemical analyses showed that indigenous processing caused a significant decrease in the level of anti-nutrients in taro, specifically tannin (66.67% reduction), cyanogenic glycoside (98.08% reduction) and oxalate (91.74% reduction). Proximate analysis showed some changes in the composition of taro after indigenous processing. The moisture content increased significantly by 13.06% after processing. The crude ash content of taro also significantly increased by 2.45% implying an increase in its total mineral content. The crude fat, crude fiber and crude protein did not significantly change after indigenous processing. Moreover, the total carbohydrates of processed taro decreased leading to a lower energy content for processed taro. Results of mineral analyses revealed that the iron and manganese content of processed taro significantly increased by 152.45 and 26.32%, respectively, after indigenous processing. The increase was correlated to the observed decrease in anti-nutrients, specifically tannin. Zinc and calcium did not significantly change after the indigenous processing despite the significant increase in crude ash content and a significant decrease in anti-nutrients especially oxalate.

The indigenous processing of taro was effective in reducing the anti-nutrient levels of tannin, cyanogenic glycoside and oxalate. It was also effective in increasing the level of crude ash and some minerals like iron and manganese. However, the increase in moisture content should not be overlooked since it can affect the shelf-life of taro. Furthermore, its deficiency in other nutrients such as iron, zinc, calcium, manganese and total carbohydrates must also be considered. The results of this study may be useful in crafting dietary interventions to alleviate malnutrition among the Obu Manuvu community. It is also recommended to study and document other indigenous processing methods employed by the Obu Manuvu and other indigenous groups in Davao City for proper knowledge transfer, awareness and recognition.

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