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Effect of Processing on the Oxalate and Calcium Concentrations of Two Local Dishes, Cơm Hến and Canh Chua Bạc Hà, Prepared from Taro Stems

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Abstract

Stems of sweet taro (*Colocasia esculenta*) grown in Thua Thien Huế Province in Vietnam and were used as an ingredient to prepare two local dishes, Cơm Hến and Canh Chua Bạc Hà. This study investigated the effect of simple processing treatments used to prepare these popular dishes on the total, soluble and insoluble oxalate and calcium contents of the taro stems. Raw stems were used to prepare Cơm Hến. Three treatments, removing the skin then washing and slicing, slicing and washing, or slicing and then allowing the stems to wilt overnight were compared to the whole raw stems with the skin retained. Overall, processing the stems reduced the soluble oxalate contents by a mean of 8% when compared with the original raw stems. The mean total calcium bound in the insoluble oxalate fraction of the three processing treatments was 43.3% ± 2.0%. Canh Chua Bạc Hà was prepared by boiling peeled taro stems. In this experiment the peeled stems were boiled for 10, 15 and 20 min and this resulted in 63.4%, 74.5% and 76.6% reductions in soluble oxalate content, respectively, when compared to the original peeled stems. Boiling for 20 min was the most effective way to reduce both the total and soluble oxalate contents of the stems. 39% of the total calcium in the raw taro stems was bound to the insoluble oxalate fraction and this was reduced to a mean of 17.2% ± 2.6% by the three cooking treatments.

Keywords

Washing, Slicing, Wilting, Boiling, Taro, Petioles, Total, Soluble, Insoluble Oxalates

1. Introduction

Sweet taro (*Colocasia esculenta*) is a major tropical crop that is widely grown in Vietnam. It is cultivated both in wet land, sandy soil, paddy fields and gardens [1]. Many different cultivars grow very well in the coastal, nutrient-poor sandy soils in rural Central Vietnam. It is a popular plant and the tubers, stems (petioles) and leaves have a range of uses. Taro tubers are used as an energy-rich food, while taro stems are processed as a vegetable. Leaves and stems are also used as feed for livestock, especially for pigs, as the crude protein content of leaves ranges from 4.7% to 6.2% wet matter (WM); for the stems it ranges from 0.5% to 0.6% WM [2].

The mineral content of commonly-consumed Vietnamese vegetable plants has not been widely researched; in particular, the calcium content of the leaves and stems of taro has not been determined. This is important, as the calcium intakes of children in Vietnam are known to be more than 50% below recommendations [3] and many recommendations suggest an increased consumption of milk and milk products [4]. An understanding of the calcium content of commonly-consumed vegetables, such as taro stems, could assist with this problem. It is important to determine the total calcium contents of these vegetable foods and to determine whether the calcium in the tissues will be absorbed when consumed, as it is known that compounds, such as oxalates, can interfere with the absorption of some minerals.

Taro stems are the most liked part of Mon Ngot (sweet taro) as they are eaten raw as the main ingredient of Cơm Hến, or cooked to prepare Canh Chua Bạc Hà. Approximately one tonne of taro stems is processed and consumed every day by local people and tourists in the 300 small restaurants in Huế city, as well as being sold by street vendors. Cơm Hến is the most well-known dish in Huế city. Canh Chua Bạc Hà is another well-known dish where cooked taro stems are mixed with fish, tomatoes and pineapples. However, earlier studies have shown that all parts of the taro plant contain high levels of soluble and insoluble oxalates; important anti-nutritive compounds [5]-[10]. Recent studies of four common cultivars of *C. esculenta* So Trang, Tron, Tia and Chum, contained a mean of total oxalates of 635.2 ± 92.4 mg/100g WM and 227.9 ± 43.6 mg/100g, WM, respectively, of soluble oxalates in freshly harvested taro leaves [11]. In an earlier study, Hang *et al.* [12] showed that the petioles of common cultivars of taro grown in central Vietnam contained significantly higher amounts ($P < 0.05$) of total and soluble oxalates when compared to the levels in the leaves. Hang *et al.* [10] were able to show that simple processing techniques, such as wilting, soaking and washing in water, were effective in reducing the soluble oxalate contents of locally-grown leaves and stems of one cultivar of taro (*Alocasia odora*). Cooking stems and a mixture of stems and leaves for between 10 and 60 min was an effective way to reduce the soluble oxalate content. The total oxalate in stems ranged from 180 - 331 mg/100g WM [9]. These studies showed that total oxalates can be reduced by ensiling (36.8%), boiling (48.4%), soaking (23.5% to 69.5%), wilting (5.9% to 14.2%) and washing (9.2%) [9] [10].

The regular consumption of foods containing high concentrations of soluble oxalates is of concern because of the harmful effects they cause when absorbed into the body. High soluble oxalate diets are widely known to cause an excessive urinary excretion of oxalate (hyperoxaluria), which causes an increased risk of developing calcium oxalate-containing kidney stones. About 75% of all kidney stones are composed mainly of calcium oxalate [13]. Therefore, people predisposed to forming kidney stones are recommended to minimise their intake of foods high in oxalates [14]. It has been reported that the greater part of the oxalic acid in plants is present in the form of soluble oxalates [15] in combination with Na^+, K^+ or NH_4^+ [16]. In addition, soluble oxalates in the diet can decrease the bioavailability of various cations, including calcium [17], magnesium and iron by forming insoluble oxalates.

Since sweet taro grows readily in many different environments in Central Vietnam and is a very popular base for many local dishes, it is important to investigate the most efficient ways to reduce the oxalate content of taro petioles when used raw to make Cơm Hến, or cooked in Canh Chua Bạc Hà, and to determine the effect of oxalates on the available calcium content of the raw and processed stems.

2. Materials and Methods

Thirty kg of stems of Mon Ngot (sweet taro) were harvested in early morning in September 2016 from Huong Chu village, in the Huong Tra District of Thua Thien Huế Province, Vietnam. Ten kg each of fresh petioles were used to prepare either Cơm Hến or Canh Chua Bạc Hà.

2.1. Preparation of Cơm Hến

The outer skin was removed from the stems, which were then processed using three different methods: washing and then slicing into 30 mm length pieces; thinly slicing and then washing; thinly slicing and allowing the petioles to wilt overnight.

2.2. Preparation of Canh Chua Bạc Hà

The stems were cooked using three different cooking times. The taro stems were washed, peeled to remove the outer skin, and then cut into 30 mm lengths. Three different batches of 500 g of processed taro were then placed in 2 L of boiling tap water and cooked for 10, 15 or 20 min. The cooked samples were then allowed to cool at room temperature, 26˚C ± 1˚C, and then the excess fluid was allowed to drain off for five min.

2.3. Sample Preparation

Three representative 300 g samples of material from each of the processing methods were dried in an oven set at 65˚C, ground to a fine powder using a Sunbeam multi grinder (Model no. EMO 400 Sunbeam Corporation Limited, NSW, Australia), then sealed in plastic bags until analysis could commence. The residual moisture was determined in triplicate [18] by drying to a constant weight in a 105˚C oven for 24 h.

2.4. Oxalate Determination

The total and soluble oxalate contents of the individual finely ground samples (~0.5 g) were determined using the method outlined by Savage *et al.* [19]. Each sample was extracted to measure the total oxalate content and three replicates were extracted to measure the soluble oxalate contents. Forty mL of 0.2 M HCl (Aristar, BDH Chemicals, Ltd., Poole, Dorset, UK) were added to the flasks for the total oxalate extraction and 40 mL of high purity water were added for the extraction of soluble oxalates. All flasks were placed in an 80˚C shaking water bath for 20 min. The solutions were allowed to cool to 20˚C and then made up to 100 mL with 0.2 M HCl for total oxalate, and high purity water, for soluble oxalate, respectively. The extracts in the volumetric flasks were filtered through a cellulose acetate syringe filter with a pore size of 0.45 µm (dismic-25cs, Advantec, California, USA) into 1 mL glass high performance liquid chromatography (HPLC) vials. The samples were analysed with a HPLC system, using a 300 mm × 7.8 mm Rezex ion exclusion column (Phenomenex Inc., Torrance, CA, USA) attached to a Cation-H guard column (Bio-Rad, Richmond, CA, USA) held at 25˚C. The analysis was performed by injecting 20 µL of each sample or standard onto the column using an aqueous solution of 25 mmoL sulphuric acid (HPLC grade Baker Chemicals, Phillipsburg NJ, USA) as the mobile phase, then pumped isocratically at 0.6 mL/min, with peaks detected at 210 nm. The HPLC equipment consisted of a Shimadzu LC-10AD pump, CTO-10A column oven, SPD-10Avp UV-Vis detector (Shimadzu, Kyoto, Japan) and a Waters 717 plus auto-sampler (Waters, Milford MA, USA). Data acquisition and processing were undertaken using the Peak Simple Chromatography Data System (Model 203) and Peak Simple software version 4.37 (SRI Instruments, Torrance CA, USA). The oxalic acid peak was identified by comparing the retention time with a standard solution and by spiking an already-filtered sample containing a known amount of oxalic acid standard. The insoluble oxalate content was calculated by the difference between the total and soluble oxalate contents [20]. The final oxalate values of all samples were converted to mg/100g WM of the original material, taking into account the moisture content of each sample.

2.5. Calcium Determination

Total calcium content was analysed using an atomic absorption spectrometer (AOAC, method 945.46) [21]. Calibration of the instrument was performed using commercial standards following AOAC method 991.25 [21]. The calcium bound in insoluble oxalate was calculated, assuming that insoluble oxalate was predominantly calcium oxalate and that calcium comprised 31.28% of this molecule.

2.6. Statistical Analysis

All analyses were carried out in triplicate and the results are presented as mean values ± standard error. Statistical analysis was performed using one-way analysis of variance (Minitab version 16, Minitab Ltd., Brandon Court, Progress way, Coventry, UK).

3. Results

Taro stems were often eaten raw and sliced in Cơm Hến and then mixed with other ingredients, but the pre-treatments given to the petioles were important in the preparation of this dish. Removal of the outer skin, slicing and washing the stems reduced the mean total and soluble oxalate content oxalate content by 7% and 9%, respectively (Table 1). Compared to the initial raw stems, removing the outer skin, washing, slicing and allowing the slices to wilt was not effective at reducing the total oxalate of the stems; however, the soluble oxalate was reduced by 6.3% when compared to the original whole stems with the skin on (Table 1). The total calcium content of the raw and processed stems were very similar (mean 87.5 ± 1.9 mg/100g WM) except that the stems that had been allowed to wilt appeared to contain a higher calcium content (116.9 mg/100g WM); most of this effect was caused by a loss of moisture during wilting. Overall, a mean 43.3% ± 2.0% of the total calcium content of the raw and processed stems was bound to the insoluble oxalate fraction and would be unavailable for absorption when consumed.

Canh Chua Bạc Hà is a popular dish in Vietnam where the stems are boiled with the other ingredients. To prepare this dish, the outer skin of the stem was removed and then slices were cut from the stems and placed in boiling water. Table 2 shows that there were marked reductions in the total, soluble and inso-

Table 1. Dry matter, oxalate, and calcium content of raw processed taro stems (mg/100g WM) used to prepare Cơm Hến (values in brackets are % of soluble oxalate in the total oxalate).

Process	Dry matter (mg/100g WM)	Total oxalate	Soluble oxalate	Insoluble oxalate	Total calcium (mg/100g WM)	Calcium bound in insoluble oxalate (mg/100g WM)	Bound calcium (%)
Whole stems with skin	6.28 ± 0.07ab	310.8 ± 3.3ab	180.6 ± 16.4a (58.1)	130.1 ± 13.3a	87.3 ± 9.3a	40.7 ± 4.2a	46.7 ± 0.8a
Skin removed, washed then sliced	6.11 ± 0.07b	299.3 ± 0.6b	174.8 ± 15.7a (58.4)	124.5 ± 15.8a	84.2 ± 11.6a	39.0 ± 5.0a	46.4 ± 1.0a
Skin removed, then sliced and washed	5.69 ± 0.09c	276.4 ± 3.3c	153.7 ± 8.1a (55.6)	122.8 ± 11.4a	90.9 ± 6.2a	38.4 ± 3.6a	42.1 ± 1.0b
Skin removed and then sliced washed and wilted for 18 h	6.52 ± 0.04a	311.7 ± 2.4a	169.2 ± 11.6a (54.3)	142.5 ± 9.3a	116.9 ± 5.3a	44.6 ± 2.9a	38.1 ± 0.7c

Means with different letters within each column differ ($P < 0.05$).

Table 2. Dry matter, oxalate and calcium content of raw and cooked taro stems (mg/100g WM) used to prepare Canh Chua Bạc Hà. (values in brackets are % of soluble oxalate in the total oxalate content).

Process	Dry matter (mg/100g WM)	Total Oxalate (mg/100g WM)	Soluble oxalate (mg/100g WM)	Insoluble Oxalate (mg/100g WM)	Total calcium (mg/100g WM)	Calcium bound to insoluble oxalate (mg/100g WM)	Bound calcium (%)
Raw	6.11 ± 0.06a	299.3 ± 0.6a	174.8 ± 15.7a (58.4)	124.5 ± 15.8a	84.2 ± 11.6a	84.2 ± 5.0a	39.0 ± 1.0a
10 minutes	5.13 ± 0.04b	137.2 ± 0.9b	63.9 ± 0.7b (46.6)	73.32 ± 1.1b	107.8 ± 4.6a	22.9 ± 0.4b	21.3 ± 0.6b
15 minutes	4.50 ± 0.03c	94.5 ± 2.4c	44.6 ± 0.1b (47.2)	49.9 ± 2.5b	88.4 ± 1.4a	15.6 ± 0.8b	17.6 ± 0.7b
20 minutes	4.03 ± 0.05c	73.1 ± 2.4d	35.7 ± 0.5b (48.8)	37.4 ± 1.9b	93.8 ± 5.5a	11.7 ± 0.6b	12.5 ± 0.5b

Means with different letters within each column differ ($P < 0.05$).

luble oxalate contents of the sliced stems following removal of the outer skin and subsequent boiling. The most effective reduction of soluble oxalate occurred after 20 min boiling (79.6% reduction), while boiling the sliced stems for 10 min gave a 63.4% reduction in soluble oxalate content. The overall mean total calcium content of the raw and cooked stems was 93.6 ± 4.9 mg/100g WM and this was not significantly changed by cooking.

Overall, 39.0% of the total calcium content of the raw stems was bound to the oxalate, making it insoluble. However, the three cooking treatments significantly reduced ($P < 0.05$) the insoluble oxalate content of the cooked stems, resulting in a significant reduction ($P < 0.05$) in the amount of bound calcium in the stems of the three cooking treatments (mean 17.2% ± 2.6%). Overall, there was a mean reduction of 56.2% in the amount of bound calcium in the cooked stems when compared to the bound calcium in the raw stems.

4. Discussion

Earlier studies [9] have shown that the stems of nine different taro cultivars grown in Vietnam in an earlier season, and under different growing conditions, ranged from 132 to 244; from 8.5 to 163 and from 44.6 to 217 mg/100g WM of total, soluble and insoluble oxalates, respectively. In this earlier study, Mon Ngot stems had values for total, soluble and insoluble oxalate of 192, 109 and 83 mg/100g WM, respectively, which were much lower than the values reported in this study (**Table 1**).

Taro consumption is affected by the presence of an acridity factor, which causes a sharp irritation and burning sensation in the throat and mouth on ingestion [22]. Presumably, the irritation arose when calcium oxalate crystals were released and inflicted minute punctures in the mouth and throat. The acridity factor can be reduced by soaking and fermentation during processing [23] [24]. The results in **Table 1** show that simple treatments, such as removing the outer skin, washing and slicing the taro stems before preparing the Cơm Hến dish, were not very effective at reducing the oxalate levels in the final products.

The total oxalate content was significantly reduced ($P < 0.05$) compared with the initial raw stems; however, wilting the stems had no effect on the total oxalate content. These physical treatments had no effect on the insoluble contents of the stems. It can be seen that removing the skin, slicing and then washing the petioles, reduced the soluble oxalate content more than when the stems were washed and then sliced into thin 30 mm slices. Washing the sliced stems allowed more oxalate to leach out from the tissue. But the value observed was not significantly different from the original whole raw stems. No reduction in soluble oxalate content was observed when the sliced stems were allowed to wilt overnight. The most interesting feature of this study was that small reductions in the percentage of bound calcium could be observed when the stems were wilted and also when the stems were washed after being sliced.

Boiling was the most effective way to reduce the soluble oxalate content of the taro stems (**Table 2**). Traditional cooking of chopped taro stems was normally carried out for 10 to 15 min. In this experiment, the stems were cooked for 20 min to investigate whether an additional cooking time would further reduce the soluble oxalate content. The soluble oxalate content was, indeed, reduced when the sliced stems were boiled for an increased time. In fact, a 63.4% reduction in soluble oxalate occurred after boiling for 10 min compared to the original raw stems and reductions of 74.5% and 79.6% in the soluble oxalate content occurred after boiling for 15 and 20 min, respectively. These results were similar to values reported by Iwuoha and Kalu [25], where 82.1% and 61.9% oxalate reductions in cocoyam flour occurred when the flour was boiled and roasted, respectively. Hang *et al.* [10] reported similar findings when stems of Mon Cham were boiled for up to 60 min, and this reduced the soluble oxalate content by 95.4% and 73% for the stems and leaves of Chia Voi, respectively. However, cooking the taro leaves and stems for 10 min led to a mean 62.1% reduction in soluble oxalate contents.

The total calcium contents of taro stems have not often been recorded but the levels of total calcium were very similar (mean 94.8 ± 7.5 mg calcium/100g WM) for the four physical treatments (**Table 1**); cooking had no effect on the total calcium content (mean 96.7 ± 5.8 mg calcium/100g WM). It was interesting to note the mean % calcium bound/total calcium was 43.3 ± 2.0 (**Table 1**). This markedly reduced to a mean of 17.1 ± 2.6 when the stems were cooked (**Table 2**). These values were relatively high when compared to the values reported by Oscarsson and Savage [7] for the proportion of insoluble calcium bound to total calcium in young growing taro leaves (10%). Overall, the reduction in total calcium bound to the insoluble oxalate fraction in the taro stems following cooking made a very positive improvement in the nutritive value of this interesting food product.

5. Conclusion

This experiment showed that simple processes, such as peeling and wilting, were not effective ways to reduce the soluble oxalate of raw taro stems. Cooking not only reduced the soluble oxalate content but also reduced the proportion of calcium bound to insoluble oxalate in the stems and was an effective way to minimize the risks of oxalate consumption from taro stems. It was possible that small adjustments to the preparation techniques would allow further reductions in the soluble oxalate content to be established and this would improve the long term nutritional value of these dishes.

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