International Food Research Journal 21(4): 1583-1588 (2014)
Journal homepage: *http://www.ifrj.upm.edu.my*

Calcium oxalate reduction during soaking of giant taro (*Alocasia macrorrhiza* (L.) Schott) corm chips in sodium bicarbonate solution

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Article history

Received: 5 July 2013
Received in revised form: 11 February 2014
Accepted: 12 February 2014

Keywords

Acridity
Concentration
Degradation
Safe level
Sodium bibicarbonate
Temperature

Abstract

The objective of this study was to investigate the effect of sodium bicarbonate concentration, time and temperature on the calcium oxalate reduction in giant taro (*Alocasia macrorrhiza* (L.) Schott) corm chips during treatment using sodium bicarbonate solution. Prior to the main study, a proximate analysis was carried out to obtain the chemical composition of taro tuber. To achieve that objective, giant taro corm chips were soaked in sodium bicarbonate solution with different concentrations, soaking times and temperatures, and the changes in calcium oxalate content was investigated. The proximate analysis of the giant taro corm showed that the corm is rich in carbohydrate, protein, minerals and fiber, but contains less fat. The changes in sodium bicarbonate concentration, soaking time and temperature led to significant ($p \leq 0.05$) reductions in the calcium oxalate content. From the technical and economics considerations, the relatively good condition to reduce the calcium oxalate content is by soaking giant taro corm chips in 2% w/v sodium bicarbonate solution for 20 minutes at ambient temperature. That processing condition resulted final calcium oxalate content in the corm chips of about 67.67 mg/100 g or slightly below the threshold safe level, which is 71 mg/100 g.

Introduction

Giant taro (*Alocasia macrorrhiza* (L.) Schott) is a member of family *Araceae* and is a native of the tropical region between India and Indonesia, and being widely cultivated in the Asia-Pacific regions (Matthews, 2004). Giant taro plant produces edible corm (Chay-Prove and Goebel, 2004), which is very rich in carbohydrates, ranging between 73 to 80% which is mainly starch at 77.9% and 1.4% crude fiber, Dry Matter (DM) basis. Thanks to its high carbohydrate content, this corm has been utilized as staple food in many parts of the tropics and sub-tropics providing about a third of the food intake of more than 400 million people (Soudy *et al*., 2010). Giant taro is also a good source of dietary protein, thiamin, riboflavin, iron, phosphorus and zinc and a very good source of vitamin B6, vitamin C, niacin, potassium, copper and manganese (Soudy *et al*., 2010). In addition, corms of taro family are especially useful to persons allergic to cereals and can be consumed by children who are sensitive to milk (Huang *et al*., 2007).

When a crop is being utilized as a food source, nutritional value and consumer acceptance have to be taken into consideration. The nutritional value of foods depends largely upon their nutritional contents, digestibility and the presence or absence of antinutrients and toxic factors (Alcantara *et al*., 2013). Most taro cultivars taste acrid and can cause swelling of lips, mouth and throat if they are eaten raw. This acridity is caused by an antinutrient namely calcium oxalate presents as fine needle-like crystals or raphides, which can penetrate soft skin (Bradbury and Nixon, 1998). Thereafter an irritant presents on the raphides, probably a protease can cause discomfort in the tissue (Paull *et al*., 1999). The reduction in calcium oxalate content may be done to raw giant taro through washing, peeling, dicing, soaking overnight, blanching and drying (Shanthakumari *et al*., 2008; Alcantara *et al*., 2013).

As far as reported in the literatures, giant taro corm is served either as staple or mixed with other vegetables, usually after cooking. Iwuoha and Kalu (1995) suggested that appropriate cooking may reduce the raphides, which cause harsh and sharp irritation in the throat and mouth. Cooking not only may improve digestibility, promote palatability, improves keeping quality, but also makes root crops safer to eat (FAO, 1990). Unfortunately, the cooking processes may also alter the physical characteristics and nutritional value of the crops (Natella *et al*., 2010; Ezeocha *et al*., 2012). The types of cooking methods (boiling, pressure cooking and baking) differ in many areas of the world and also vary with the ethnic background of the family (Bhandari and Kawabata, 2006).

Due to its high moisture content, fresh taro corm is difficult to store and is vulnerable to deterioration

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during storage. One of the best ways to preserve it is by processing it into flour and/or starch (Perez *et al*., 2005; Aboubakar *et al.*, 2008). Therefore, it is important to investigate whether the calcium oxalate content in giant taro corms can be reduced by preparation and cooking with sodium bicarbonate solution to a safe level before being transformed into flour. The objective of this work was to investigate the effect of different soaking solution concentrations, times and temperatures on the calcium oxalate reduction during soaking of giant taro corm chips in sodium bicarbonate solution. An acquisition of understanding of the giant taro corm processing to reduce calcium oxalate content to a safe level may demonstrate its further potential uses in the food industry as an alternative source to conventional forms of carbohydrates or in production of new food products.

Materials and Methods

Materials

Giant taro (*Alocasia macrorrhiza* (L.) Schott) corms were randomly harvested at maturity (9 months after planting) from a home garden in Kudus District-Central Java (Indonesia). They were immediately sent to the laboratory and stored under prevailing tropical ambient conditions (19-28°C, 60-85% RH) before used in the experiments, normally within 1 week of harvesting. All chemicals and reagents used were of analytical grade and purchased from Sigma-Aldrich Pte. Ltd. (Singapore).

Methods

The dry matters contents were determined by drying in an oven at 105°C during 24 h to constant weight (AOAC, 1990). The crude protein contents were calculated from nitrogen contents (N × 6.25) obtained using the Kjeldahl method by AOAC (1990). The crude fat contents were determined by continuous extraction in a Soxhlet apparatus for 8 h using hexane as solvent (AOAC, 1990). The total ash contents were determined by incinerating giant taro corm in a furnace at 550°C (AOAC, 1990). The crude fiber contents were determined according to standard method (AOAC 1990). Therefore % carbohydrate = 100 - (% moisture + % crude protein + % crude fat + % crude fiber + % ash). The minerals, such as calcium and iron, were analyzed after first wet-ashing according to the method prescribed by Onwuliri and Anekwe (1992) with an atomic absorption spectrophotometer (Pye-Unicam 969, Cambridge, UK). Phosphorus contents were estimated colorimetrically (UV-visible spectrophotometer, JASCO V-530, MODEL TUDC 12 B4, Japan Servo CO. LTD Indonesia), using potassium dihydrogen phosphate as the standard (AOAC, 1990).

Prior to calcium oxalate reduction study, giant taro corms were washed with clean water and peeled using a stainless steel knife. The peeled samples were then rewashed with clean water and cut into slices (2 cm × 2 cm × 0.2 cm). Four hundreds milliliters of sodium bicarbonate solution (0, 2, 4, or 6% w/v) was poured in to a pot and heated on a hot plate at the desired temperatures (30, 40, 50 or 60°C). Approximately, 100 g of the giant taro corm chips samples were soaked inside the warm sodium bicarbonate solution and were allowed to contact for 0, 20, 40 or 60 min. The sodium bicarbonate solution was drained off after each time interval and the hot samples were exposed to the air to allow surface water to evaporate for 20 min. The slice taro corms were then mashed and subjected to calcium oxalate content analysis.

The calcium oxalate content in the fresh and processed samples was determined using the AOAC (1990) analytical method. The procedure involves three steps: digestion, oxalate precipitation and permanganate titration. Each sample was analyzed in triplicate and all data are presented as mg oxalate/100 g fresh weight (FM) as this is how this vegetable is normally consumed.

The data obtained from the studies were subjected to statistical analysis using one factor analysis of variance (ANOVA) and Turkey mean separation for multiple comparisons with the Statistical Analysis System (SAS) program (SAS Institute, 2003). Significance was accepted at $P \leq 0.05$.

Results and Discussion

Proximate composition of Indonesian giant taro corm

Prior to calcium oxalate reduction study, a proximate analysis of fresh giant taro corm has been conducted. The results of this analysis and the proximate analysis of other root crops obtained from literatures are presented in Table 1. The proximate composition of giant taro corm investigated in this study was found to be very close with that reported by Dignan *et al.* (2004). As seen in Table 1, giant taro corms contained a moderate carbohydrate content as such they are a good source of energy. However, the energy content in giant taro was found to be lower than the common taro (*Colocasia esculenta*), cassava as well as sweet potato reported in the literatures (Sefa-Dedeh and Agyir-Sackey, 2004; Charles *et al.*, 2005 and Nuwamanya *et al.*, 2011). As expected, giant taro corm was also found to be rich in protein,

Table 1. The proximate analysis of giant taro and other root crops per 100 g

Component	Taro[a]	Giant taro[b]	Giant taro[c]	Casssava[d]	Sweet potato[e]
Energy (cal)	128.97	105.12	102	113.93	105.80
Carbohydrate (g)	27.1	23.16	22.5	27.20	23.31
Protein (g)	3.99	2.1	2.2	1.8	1.13
Fat (g)	0.78	0.1	0.1	0.45	11.8
Ash (g)	1.7	1.2	1.5	1.05	0.28
Moisture(g)	63.67	74.04	70	66	63.13
Fiber(g)	0.61	1.8	1.9	3.5	0.35
Vitamin A (SI)	74.4	0.1	0	13	14187
Vitamin C (mg)	16.1	15	17.0	22.3	27.7
Thiamin (mg)	0.67	0.18	0.02	0.09	0.08
Riboflavin (mg)	0.26	0.04	0.02	0.05	0.06
Niacin (mg)	2.2	0.9	0.5	0.85	0.56
Ca (mg)	291.27	153.2	38	39	32.3
P (mg)	60.2	58.5	0.17	10.6	49
Fe (mg)	3.75	1.20	0.8	78.8	0.8

Source: [a] Sefa-Dedeh and Agyir-Sackey (2004), [b] This work, [c] Dignan *et al.* (2004), [d] Charles *et al.* (2005), [e] Nuwamanya *et al.* (2011)

but lower in fat content. High ash content found in giant taro corm indicated that it rich in minerals. These results are consistent with that reported by Bradbury and Holloway (1988) where they found that the taro corm provides good amounts of energy, high amounts of protein, iron, and manganese, and low amounts of copper, potassium, thiamine, and riboflavin. Even though the fiber content in giant taro is lower than cassava tuber, the fiber content value is still higher than both taro and sweet potato tubers. High fiber content indicates that giant taro corms could help treat constipation and hence may improve the general health and well being (Olayiwola *et al.*, 2009). Dietary fiber has recently gained much attention as it is said to reduce the incidences of colon cancer, diabetes, heart disease and some other digestive diseases (Rose and Vasanthakaalam, 2011). The analysis also revealed that freshly harvested giant taro corm has high moisture content, which is a very well-known characteristic feature of roots and tubers crops (Mbofung *et al.*, 2006). Indeed, the value is higher than that of taro, cassava and sweet potato tubers, which shows giant taro corm high potential to rot and microbial attacks.

Instead of having good nutritional content, giant taro corm also contains a considerable amount of calcium oxalate as a harmful antinutrition. The calcium oxalate content in the fresh giant taro corm investigated in this study was found to be 471.15 mg/100 g. This value agrees well to the literatures, which are 317-445 mg/100 g and 265.2-7552.5 mg/100 g for raw taro Colocasia corm from Pacific islands and Africa, respectively reported by Holloway *et al.* (1989) and Lewu *et al.* (2010). Other roots and tubers mostly only contain calcium oxalate of less than 100 mg/100 g.

Another fact to be mentioned is that there was a remarkable decrease in the concentration of calcium oxalate from the skin towards the center of the large corm of giant taro that is typically within 50-75 cm long and 10-20 cm in diameter. The calcium oxalate content in the skin of giant taro corm used in this study was 592.63 mg/100 g. While Holloway *et al.* (1989) reported that calcium oxalate content in the skin of Samoan giant taro corm was 451 mg/100 g, which is higher than that in the center of the corm (84-182 mg/100 g). From their observation by light microscopy, Sunell and Healey (1979) also found that the concentration of calcium oxalate raphides decreased from the skin to the center of taro Colocasia. The large concentration of calcium oxalate in the surface layers is consistent with Sakai (1983) statement that the acridity of giant taro is concentrated in the outer layers of the corm. Calcium oxalate content in giant taro corm depends on the cultivars, fertilizers and environmental condition, especially during drought (Bradbury and Holloway, 1988). Since the allowable calcium oxalate content in food is only 71 mg/100 g (Sefa-Dedeh and Agyir-Sackey, 2004), therefore giant taro corms require proper processing method to reduce the calcium oxalate content to a safe level.

Effect of time and sodium bicarbonate concentration on calcium oxalate reduction at ambient temperature

The processing of any natural resources into food materials will be economical if it is conducted without the use of energy from fossil fuel. From this point of view, this research began with an attempt to reduce the calcium oxalate content in the giant taro corm by soaking the giant taro corm chips into sodium bicarbonate solution at ambient temperature (±30^oC). The presence of Na^+ ions in the sodium bicarbonate solution is expected to promote the decomposition of calcium oxalate into calcium oxide (Schempf *et al.*, 1965). In addition, the presence of Na^+ ions in the sodium bicarbonate solution may also increase the solubility of calcium oxalate. Without the addition of sodium salt, the solubility of calcium oxalate in water is only 0.67 mg/g at ambient temperature (Goodenough and Stenger, 1973).

Figure 1 shows the profile of calcium oxalate content in the giant taro corm chips at various concentration of sodium bicarbonate solution, soaking time and temperatures. In Figure 1 (a) one can observe that soaking the giant taro corm chips in water (0% sodium bicarbonate solution) for 60 minutes may only reduce the calcium oxalate content from 471.15 to 439.9 mg/100 g, or about 6.63%. Unfortunately, this value remains far higher than the threshold calcium oxalate level in food, which is (71 mg/100 g) (Sefa-Dedeh and Agyir-Sackey, 2004). This phenomenon can be directly linked to low calcium oxalate solubility in water by which leaching of calcium oxalate is controlled. As a result, extending soaking time did not significantly speed up

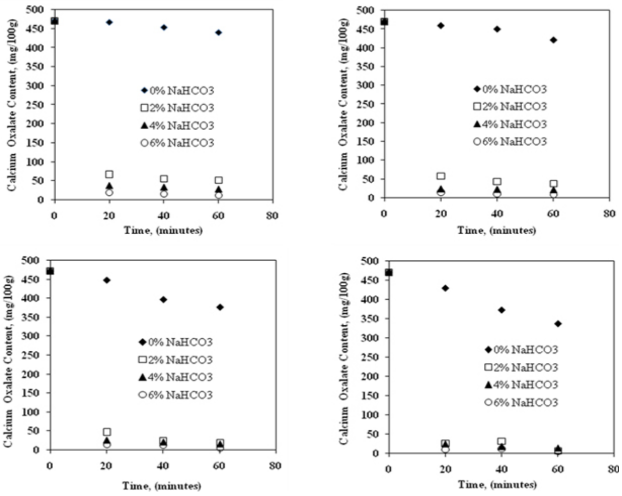

Figure 1. The profile of calcium oxalate content in the giant taro corm chip as a function of sodium bicarbonate solution concentration, soaking time and temperatures (a 30°C, b (40°C), c (50°C) and d (60°C)

the calcium oxalate reduction.

As sodium bicarbonate concentration in the soaking media increased, the calcium oxalate content left in the giant taro corm chips also decreased. In addition, the longer the soaking time also caused further decrease in calcium oxalate content in the giant taro corm chips. In general, the reduction rate of calcium oxalate in the giant taro corm chips was faster in the beginning of the process (0-20 minutes). This phenomenon may occur because the giant taro corm was sliced into chips that create broken and intact cells before being soaked in sodium bicarbonate solution. Slicing giant taro corm into chips caused some of the calcium oxalate is located at the outer surfaces of the chips or in ruptured cells and thus can be readily accessible to the sodium bicarbonate solution while the rest is deep down in the pore structure or in intact cells and then less accessible. Leaching of easily accessible calcium oxalate is very fast with a rate controlled by its diffusion in the sodium bicarbonate solution, while the leaching of the less accessible calcium oxalate from intact cells is much slower and the mass transfer resistance is high. Resistance to mass transfer in non-agitated system considered includes both the sodium bicarbonate solution film around the chips and the solid phase (i.e., within the chips). The former determines the rate of leaching of the easily accessible calcium oxalate while the latter controls the rate of mass transfer of the less accessible calcium oxalate. Unfortunately, extending the soaking time did not give a significant effect on calcium oxalate level. Giant taro corm chips with calcium oxalate content between 12.79 - 67.67 mg/100 g, which is lower than the threshold of calcium oxalate level in food, can be obtained by soaking giant taro corm chips in all studied sodium bicarbonate solutions at room temperature (±30°C) for 20 minutes or longer.

Effect of time and sodium bicarbonate concentration on calcium oxalate reduction at higher temperatures

On the basis of literature data that the solubility of calcium oxalate in water increases with increasing temperature (Goodenough and Stenger, 1973) and that the decomposition reaction of calcium oxalate crystals into calcium oxide also occurs rapidly at high temperatures (Schempf *et al.*, 1965), then a study on the effects of temperature and concentration of sodium bicarbonate to the calcium oxalate content reduction rate in giant taro corm chips was conducted. The experimental results of the study are presented in Figures 1 (b), 1 (c) and 1 (d).

As can be seen in Figure 1 (a) and (b), there is no much difference between the phenomena observed during the soaking process of giant taro corm chips in water (0% w/v sodium bicarbonate solution) at 30°C, 40°C, 50°C and 60°C. The calcium oxalate content in the giant taro corm chips reduced almost linearly at all studied temperatures. However, the slopes of the calcium oxalate content versus soaking time plots were steeper at higher temperatures. As a result, the final calcium oxalate content was lowest for giant taro corm chips treated at 60°C for 60 minutes, which is 337.85 mg/100 g. Again, these results suggest that soaking of giant taro corm chips in warm water is still unable to reduce the calcium oxalate content to safe level, which is (71 mg/100 g) (Sefa-Dedeh and Agyir-Sackey, 2004). The correlation between calcium oxalate content and time for soaking process using water at 60°C is:

$$CaOx = 471.17 - 2.271.\ t \quad (1)$$

where CaOx and t are calcium oxalate content (mg/100 g) and time (minutes), respectively. Using equation (1), one can predict the time needed for soaking giant taro corm chips in water at 60°C to reduce the calcium oxalate content to safe level, which is 176.20 minutes or about 3 hours.

Soaking giant taro corm chips in sodium bicarbonate solution with 2, 4 and 6% (w/v) concentration at 30°C, 40°C, 50°C and 60°C caused significant reduction in calcium oxalate level in the corm chips. The final calcium oxalate levels in the giant taro corm chips met the threshold of calcium oxalate level in food. Similar to reduction rate of calcium oxalate in warm water, the reduction rates of calcium oxalate during soaking of giant taro corm chips in any sodium bicarbonate concentrations at temperatures studied were faster in the beginning of the process (0-20 minutes). Prolonging the soaking time did not significantly influence the calcium oxalate level. Giant taro corm chips with calcium oxalate content between 3.83 - 67.67 mg/100 g, which is lower than the threshold of calcium oxalate level in food, can be obtained by soaking giant taro corm chips in all studied sodium bicarbonate solution concentrations and temperatures for 20 minutes or longer. It is obvious, that soaking giant taro corm chips in sodium bicarbonate solution for 20 minutes has been sufficient to reduce the calcium oxalate content to below the safe level. At 60°C, the reaction between calcium oxalate and sodium bicarbonate is faster than that at 30, 40 and 50°C, even when the concentration of sodium bicarbonate solution is as low as 2% w/v. This fact is indicated by larger reduction of calcium oxalate concentration in giant taro corm chips after being soaked in the sodium bicarbonate solution at all time and higher temperatures studied. On the whole, the results obtained from soaking of giant taro corm chips at higher temperature are indicative that calcium oxalate is a thermally labile substance. The obviously marked reduction of calcium oxalate caused by soaking at higher temperature may also be due to the synergetic effects of leaching and thermal degradation. The similar results were obtained by Iwuoha and Kalu (1995) who reported that boiling of taro corm for 60 minutes completely removed the irritant effect (calcium oxalate). However, from the technical (the use of energy, time and simplicity) and economics considerations, the relatively good condition to reduce the calcium oxalate content is by soaking the giant taro corm chips using 2% w/v sodium bicarbonate solution for 20 minutes at ambient temperature.

Conclusions

Based on the results, it can be concluded that soaking of giant taro corm chips in warm water is still unable to reduce the calcium oxalate content to safe level. From the technical and economical point of views, calcium oxalate content in giant taro corm chips can be reduced to below the threshold safe level by soaking giant taro corm chips in 2% w/v sodium bicarbonate solution at ratio 1:4 (w/v) for 20 minutes at ambient temperature. Further studies are required to investigate the possible changes in physicochemical properties of giant taro flour as affected by soaking process.

Acknowledgement

The author greatly acknowledges the Directorate of Research and Community Service, Directorate General of Higher Education, Ministry of Education and Culture the Republic of Indonesia for its financial support through National Strategic Research Grant 2012 under contract No.: 008/SP2H/PL/Dit. Litabmas/III/2012.

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