DEVELOPMENT OF EFFICIENT CALCIUM OXALATE REMOVAL TECHNIQUES FROM TARO CORMS

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Abstract

Taros (Colocusiu and Xanthosoma spp.) are tropical root crops commonly referred to as cocoyams, which have been used as subsistence staple foods in many parts of the tropics and sub-tropics in Africa and Australasia. Proximate analysis of the taro corms has shown that it contains digestible starch, protein of good quality, vitamin C, thiamin, riboflavin and niacin. However, one major limiting factor in the utilization of taros is the presence of oxalates which impart acrid taste or cause irritation when foods prepared from them are eaten. Ingestion of foods containing oxalates has also been reported to cause caustic effects, irritation to the intestinal tract and absorptive poisoning as well as disrupting the bio-availability of calcium. While several methods have been made to reduce oxalate content in taro corms, none has been reported to meet the satisfactory level of the consumers. Considering that calcium oxalate content in the skin is higher than in the tuber flesh and that physical (thermal and irradiation) degradation of calcium oxalate is more pronounced than chemical and biological degradations, a method to reduce the calcium oxalate content in the taro corms is proposed. The proposed method involves peeling, washing, steeping, boiling and drying, which is expected to remove about 93.14% of the original calcium oxalate content.

Keywords: *taro; calcium oxalate; removal; development*

INTRODUCTION

Taros *(Colocasia*) (Figure. 1) are root crops that are easily found in both the tropical and subtropical regions of the world. Taros are native to Asia, which *Colocasia esculenta* is the species that mostly grown in West Africa with Ghana and Nigeria being the main producers (Ihekoronye & Ngoddy, 1985). They are also important crops in Hawaii, Japan, and other Pacific nations. The

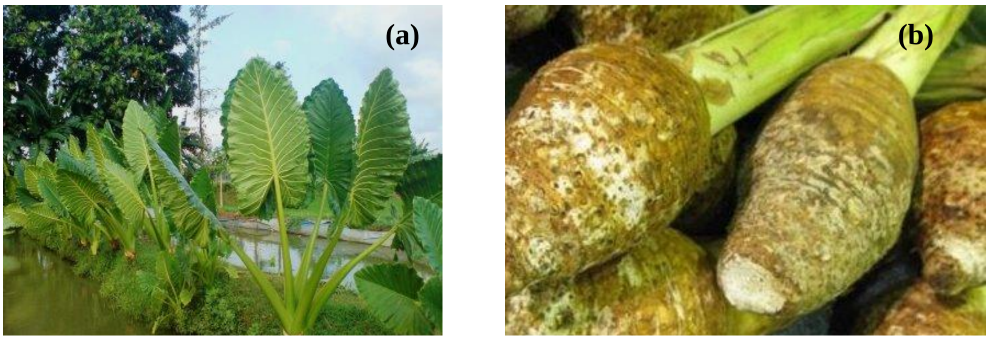

Figure 1. Taro plant (a) and Taro Corms (b)

world's annual production of this crop is predicted to be 5.5 million tones, which provides about a third of the food supply of more than 400 million people in the tropics (FAO, 1991). Taros can be processed into several food and feed products and industrial inputs as good as potatoes in the Western world. Taro corms processing is targeted for obtaining products that are stable in terms of longevity, nutrition, and palatability. Peeling, boiling, roasting, deep frying, pasting and milling are the important processing methods (Obiechina & Ajala, 1987). It has been observed that, in spite of the fact that taros are neglected crops, their compositional value is high (Agbor-Egbe and Richard, 1990) leading to their use as subsistence staple foods in many parts of the tropics and sub-tropics in Africa. They produce starch storage corms and cormels, and have several cultivars throughout the world. Proximate analysis of the taro corms has shown that they contain digestible starch, protein of good quality, vitamin C, thiamin, riboflavin and niacin Onwueme (1994).

Apart of all the above mentioned potentials, it has been reported that the consistent palatability problems associated with taros have hindered the realization of its full potentials. Bradbury & Holloway (1988) found that the causes of the antinutritional and off-taste problems have been identified as calcium oxalate crystals and other acidic and proteinaceous principles. They also reported that the content of calcium oxalate varied with the position in the corm. The content was 451, 182 and 84 mg/100 in the skin, 1 cm below skin and the centre of the corm, respectively. Ingestion of foods containing oxalates has been reported to cause caustic effects, irritation to the intestinal tract and absorptive poisoning (Sakai, 1972) and disturb the bio-availability of calcium (Guéguen and Pointillart, 2000). It occurs as the free acid, as soluble salts of potassium and sodium, and as insoluble salts of calcium, magnesium and iron (Noonan and Savage, 1999). The lethal dose of calcium oxalate to human is 2 g (Albihn and Savage, 2001). It could therefore be recommended that the intake of calcium oxalate in one meal does not exceed two-third of this lethal dose. However, the threshold level of calcium oxalate in food is 71 mg/100g (Sefa-Dedeh and Agyir-Sackey, 2004). The objective of this paper was to propose an efficient technique to reduce the calcium oxalate content in the taro corms.

LITERATURE SURVEYS ON THE CALCIUM OXALATE REMOVAL METHODS

Several attempts have been made to reduce oxalate content in taros. The peels of tubers contain more oxalate than the peeled tubers (Akpan and Umoh, 2004), therefore peeling should be the first step to do when removing calcium oxalate from tubers (Sangketkit *et al*., 2001). Removal of the thick layer of skin and long period of cooking is required to remove acridity (Crabtree and Baldry, 1982). Onayemi and Nwigwe (1987) observed that soaking of sliced taro corms in water and in solutions of citric acid and EDTA reduced the oxalate levels ranging from 9 to 26%. Steeping of taro slices in water at 30 ^{o}C for 24 hours was reported to reduce the oxalate-salt content 35% of its original content, respectively (Iwuoha and Kalu, 1995). In other investigation, soaking of taro in 0.05% w/v NaOH solution with taro-NaOH solution ratio of 1:4 for 2 hours followed by drying in the electric oven at 40^{o}C for 16 hours, reduced calcium oxalate content by more than 40% (Tattiyakul *et al.*, 2006). While no detail information was given in their article, Carpenter and Steinke (1983) reported that anaerobic fermentation, baking or extraction with ethanol also helps in the reduction of acridity levels in taro. Fermentation in water affected a significant reduction in oxalate level (58 to 65%) depending on the fermentation period (Oke and Bolarinwa, 2012).

Osisiogu *et al*. (1974) observed that boiling of taros for 15 min brought about considerable reduction in the irritant effect. They concluded that the irritant principle of taros could be destroyed by volatilization and not by heating. In another study, boiling for 30 min at 90^{o}C removed about of the irritant substance (Iwuoha and Kalu, 1995), indicating that irritation and itching caused by the acridity factor may not be observed when taro is thoroughly cooked (Agwunobi *et al*. 2000). Albihn and Savage (2001) observed that repeated boiling for 15 minutes with changes the water every boiling reduced the calcium oxalate content in taro corm. Akpan and Umoh (2004) used of heat treatment and different concentrations of tetracycline during cooking to reduce the level of acridity in taro. Boiling for 40 minutes caused significant reduction of calcium oxalate of Japanese taro (Catherwood *et al.*, 2007). Similar results were reported previously by Savage *et al*. (2000), Savage (2002) and Quinteros *et al*. (2003).

Although it has been reported that the traditional methods including drying of taros may reduce oxalate (Purseglove, 1972), they do not completely remove it as itching is still reported by many consumers (Onayemi & Nwigwe, 1987). The trend of oxalate levels obtained from oven drying, observed for the 24 h dried samples, was not different from that obtained in the 12 h dried samples (Sefa-Dedeh and Agyir-Sackey, 2004), which was from 302 to 200μg/100g (33.77%). Drum-drying reduced oxalate levels by approximately 50% to average levels ranging from 99.9 to 192 μg/100 g (Sefa-Dedeh and Agyir-Sackey, 2004) from its original value between 302-309 μg/100g. High temperature is known to cause the calcium oxalate-containing cells (raphides) to collapse, leading to the breakdown of oxalate structure. The trend of oxalate levels observed for the 24 h solar dried samples was not different from that obtained in the 12 h dried samples (Sefa-

Dedeh and Agyir-Sackey, 2004) from 302 to about 100μg/100g (66.89%). It is clear that solar drying performes better calcium oxalate reduction than oven drying. Roasting of taro corm at 165°C within 40-45 min reduces about 54.56% of its calcium oxalate content (Iwuoha and Kalu, 1995). However, more recent investigation reported that baking was found to increase the calcium oxalate content in dry matter (Albihn and Savage, 2001). Similar results were reported by Savage *et al*. (2000), Savage (2002), Quinteros *et al*. (2003) and Savage and Martensson (2010).

Despite all these efforts, there is little information about the detail and efficiency of the various processes in relation to the measured parameter(s). In addition, the available reports about the effects of processing on oxalates appear conflicting and inconclusive.

THE CALCIUM OXALATE DEGRADATION

As far as the literature surveys were done, the degradation of calcium oxalate might occur through the following manners:

1. Thermal degradation

$$CaC_2O_4 . n\, H_2O_{(s)} \rightarrow CaC_2O_{4\,(s)} + n\, H_2O_{\,(g)}$$

$$CaC_2O_{4(s)} + heat \rightarrow CaCO_{3(s)} + CO_{\,(g)}$$

$$CaCO_{3(s)} \rightarrow CaO_{(s)} + CO_{2\,(g)}$$

The presence of Na^+ ions was found to increase the decomposition rate and reduce the activation energy of the above reaction. The Na^+ ions act as a catalyst for the decomposition reaction (Schempf *et al*., 1965).

2. Irradiation degradation: Gamma ray irradiation increased the decomposition rate of calcium oxalate (Basahel *et al*., 1987). This conclusion was based on their observation where morning and afternoon sun drying caused different efficiency due to different sunlight intensity and rays composition.

3. Biological degradation: Anaerobic fermentation helps in reduction of acridity levels in taro (Carpenter and Steinke, 1983). In addition, uncontrolled fermentation of taro chips (2-2.5 cm thickness) in water reduced their calcium oxalate content (Oke and Bolarinwa, 2012).

THE CALCIUM OXALATE REMOVAL METHOD DEVELOPMENT

Based on the degradation mechanisms of calcium oxalate and the previous investigations by other researchers on the reduction of calcium oxalate in taro corms as affected by cooking methods, an efficient technique to remove the calcium oxalate from taro corms in developed. With the facts that discrepancy was reported by previous researchers on the effects of baking as an example of dry thermal treatment on the reduction of calcium oxalate, two options are given to whether or not using these techniques. The schematic diagram of the proposed calcium oxalate removal method is depicted in Figure 2.

Holland *et al.* (1991) reported that the taro corm contains about 5 g skins for 100 g corm. Therefore, removal of the skin from the corm will reduce 15% of the total calcium oxalate content in the corm. If the average calcium oxalate content in the taro corm is about 590 mg/100 g corm (Iwuoha and Kalu, 1995), then the expected concentration of calcium oxalate in the product dried taro chips will be 38.8 mg/100 g corm. This value is about a half of the threshold levels of calcium oxalate (71 mg/100g) in food products as suggested by Sefa-Dedeh and Agyir-Sackey (2004).

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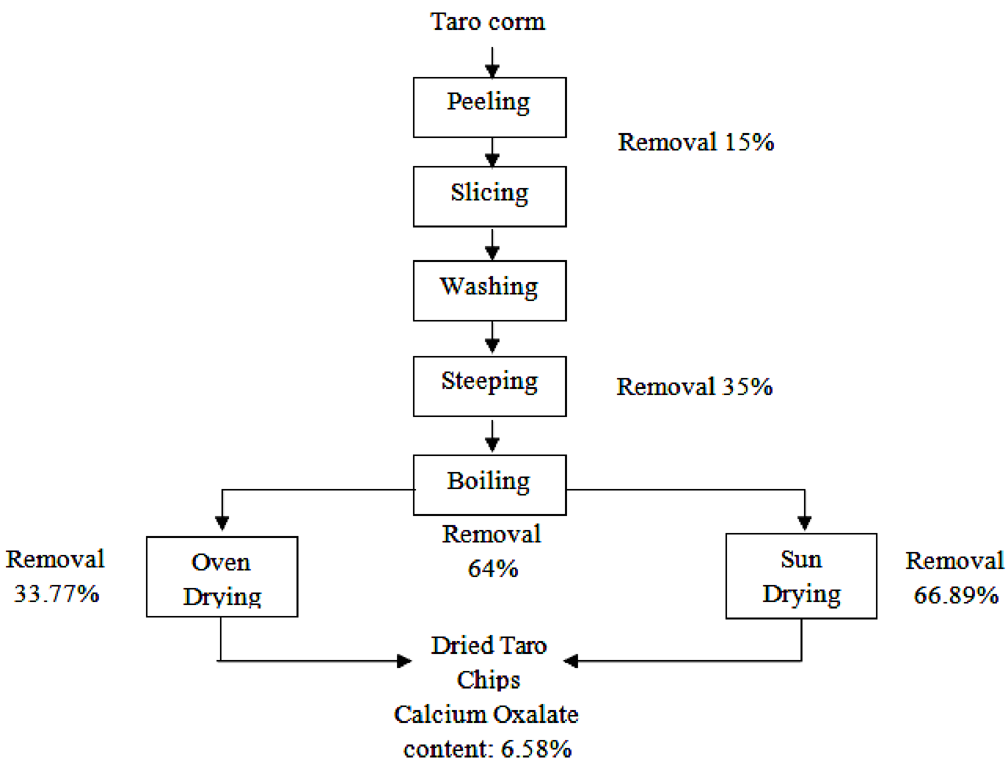

Figure 2. The Schematic Diagram of Calcium Oxalate Removal from Taro Corm

CONCLUSIONS

A method has been developed to reduce the calcium oxalate content of taro corm to a safe level based on the calcium oxalate degradation mechanism and effects of cooking methods on the calcium oxalate reduction. The proposed method involves peeling, washing, steeping, boiling and drying, which is expected to remove about 93.14% of the original calcium oxalate content.

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