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In vitro availability of some essential minerals in commonly eaten processed and unprocessed Caribbean tuber crops

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Abstract

The levels of three essential minerals Ca, Fe and Mg and the extent of their availability were assessed in four commonly eaten Caribbean tuber crops [dasheen (*Xanthosoma* spp.), Irish potato (*Solanum tuberosum*), sweet potato (*Ipomoea batatas*) and yellow yam (*Dioscorea cayenensis*)] in their processed and unprocessed states. Calcium was highest in cooked dasheen (5150 ± 50 mg/kg) while Magnesium was highest in uncooked Irish potato (3600 ± 200 mg/kg). There was no significant loss of calcium from the food samples upon cooking. All the uncooked food samples displayed higher levels minerals assessed compared to the cooked samples except for cooked Irish potato that recorded the level of iron (182.25 ± 8.75 mg/kg). Availability of these minerals in the cooked and uncooked tubers crops upon digestion also showed a similar pattern. In conclusion, the consumption of these tuber crops in the Caribbean may not be responsible for the reported cases of iron deficiency in the region. However, the availability of minerals from these tuber crops when consumed with other foods (the usual practice in the Caribbean) needs further investigation.

Introduction

Roots and tubers are thickened underground starch storage organs of some plants (Eka 1998). Some of the staple tuber crops in the Caribbean are yellow yam (*Dioscorea cayenensis*), Irish potato (*Solanum tuberosum*), sweet potato (*Ipomoea batatas*) and dasheen (*Xanthosoma* spp.).

Sweet potato is a root tuber, Irish potato and dasheen are stem tubers while yam is intermediate between roots and stem tuber (Onwueme & Charles 1994). For simplicity, all these crops are referred to collectively as tuber crops, a term which, unlike 'root crops' does not confer any connotations as to morphological origin. With mineral deficiency being a major problem to nutritionists, researches are aimed at investigating the mineral levels and the extent of mineral bioavailability in commonly consumed food crops. Bioavailability can be defined as the proportion of the total mineral in a food, meal or diet that is utilized for normal body functions (Fairweather-Tait 1992). Several factors may contribute to the extent of mineral bioavailability including, maturity of the food, processing methods employed and the presence of antinutritional factors.

Tuber crops are consumed on a wide scale in the tropics as well as in the Subtropical regions (Onwueme & Charles 1994). The availability of minerals from these tuber crops in the Caribbean has not been investigated. This is important because there are reported cases of iron deficiency in Jamaica (Simmons 1990).

This study was therefore aimed at assessing the levels of some essential minerals in commonly eaten Caribbean tuber crops. One of these minerals is of special interest because the deficiency is common not only in developing countries where the diet is essentially composed of cereals and root crops, but also in some industrialized countries (Welch & Graham, 1999). We assessed the availability of minerals by simulating *in vivo* digestion using *in vitro* methods. Physiological studies were not done in this study hence the level of minerals released bears no indication to the amount which would be eventually absorbed. It only denotes availability.

Materials and methods

Materials

The following tuber samples were selected, yellow yam (*Dioscorea cayenensis*), sweet potato (*Ipomoea batatas*), Irish potato (*Solanum tuberosum*), and dasheen (*Xanthosoma* spp.) were collected from the Lower River extension area of Trelawney, Jamaica. The samples were washed, peeled, diced and oven dried to constant weight. The samples were then crushed in a laboratory mill and kept at 2–5 °C for further use. Similar samples were also cooked (after removal of the skin) in de-ionized water then dried to constant weight. They were then milled and stored as before.

Methods

Determination of mineral elements

Minerals were determined according to standard AOAC methods (AOAC 2000). A known weight of ground sample (1.0 g) was weighed into a 100 ml porcelain crucible, placed in a cold furnace and the temperature raised gradually to 500 °C. These samples were ashed overnight after which they were treated with 1.0 ml of concentrated nitric acid and evaporated to dryness over a hot plate. The residue was returned to the furnace and ashing continued for another hour (this is done only if ashing is incomplete). A small volume (5 ml) of 20% HCl was added to the sample which was then covered and digested at low heat for about 15 min. After cooling the solution was made up 25 ml with de-ionized water. Samples were read using a Unicam 939 atomic absorption spectrophotometer equipped with background correction and cathode lamps.

The determination of mineral components in the samples was carried out using a nitrous oxide/acetylene mixture, at the following wavelengths: 422.7 for calcium and 248.3 for iron. A slit width of 0.2 mm was used for Iron and Magnesium while 0.7 mm was used for Calcium.

When determining the calcium content, a solution of lanthanum chloride was added to all the analyzed solutions and reference samples to attain a 0.5% concentration of La^{3+}.

The accuracy of the analytical method was confirmed through a series of certified analyses on reference materials. Appropriate spikes were added to specific samples for recovery determinations.

Enzymatic digestion

The availability of minerals from these commonly eaten tuber crops was assessed after *in vitro* enzymatic digestion followed by further analyses of the residues and filtrates.

The degree of release of minerals during *in vitro* digestion was carried out according to the method of Ikeda (1990) with modifications. De-ionized water (10 ml) was added to 1.0 g of sample and supplemented with sodium azide to a final concentration of 0.025%. The solution was then brought to pH 2.0 with 1 M HCl after which pepsin solution was added at the level of 0.5 g enzyme per 100 g. Incubation of the samples followed at 37 °C for 2 hours. The pH of the solutions were monitored during this period and adjusted by adding 2 M HCl where necessary. After the incubation period, the pH of the solutions was raised to 6.8–7.0 by adding 6% $NaHCO_3$ solution. A solution of Pancreatin (0.4%) was added at the rate of 10 ml per 40 ml of sample solution then incubation followed for 4 hours. The mineralized sample was centrifuged at 4000 rpm for 30 min and decanted by draining through medium-hardness paper. Ashing of the sample was done as described earlier. The filtrates were also analyzed for their mineral contents.

Statistical analysis

Statistical analyses. Results were expressed as means ± SEM. Analysis of Variance (ANOVA) was used to test for difference between the groups. Duncan's Multiple Range Test was used to test for significant difference among the means and $P < 0.05$ was taken as significant Sokal and Rolf (1969).

Results

Figure 1 shows Calcium levels in selected tuber crops and their corresponding filtrates after *in vitro* digestion. Of the tuber samples analyzed, dasheen displayed the highest levels of calcium with values of 5150 ± 50 mg/kg for the cooked samples. The lowest levels were recorded for the cooked samples of yellow yam (300 ± 11 mg/kg). Interestingly, similar levels of calcium were observed in both the cooked as well as the uncooked samples of Irish potato (1200 ± 100 mg/kg). Higher values for calcium were observed in uncooked samples of yellow yam (410 ± 10 mg/kg), sweet potato (2400 ± 115 mg/kg) and dasheen (5150 ± 50 mg/kg) than in the cooked samples which had values of 300 ± 11 mg/kg, 1500 ± 59.2 mg/kg and 4150 ± 650 mg/kg, respectively. Overall, no significant loss of calcium was from the food samples upon cooking.

Figure 2 shows Iron levels in commonly consumed food samples and their corresponding filtrates after *in vitro* digestion. Iron levels were generally higher in the uncooked samples compared to the cooked samples. Uncooked and cooked yellow yam had values of 106.9 ± 41.1 mg/kg and 79.95 ± 3.25 mg/kg, respectively, while uncooked and cooked sweet potato had values of 91.75 ± 15.25 mg/kg and 79.4 ± 9.8, respectively. Cooked and uncooked samples of dasheen had iron levels of 152 ± 3.25 mg/kg and 81.45 ± 1.45 mg/kg, respectively. This is expected as upon cooking, mineral levels may decrease due to leaching of these minerals into the cooking medium. An exception to this was observed in the case of Irish potato wherein iron levels in the cooked samples (187.25 ± 8.75 mg/kg) were actually higher than in the uncooked samples (73.7 ± 6.7 mg/kg).

Figure 3 shows magnesium levels in commonly consumed food samples and their corresponding filtrates after *in vitro* digestion. All the uncooked food samples displayed higher magnesium levels compared to the cooked samples. These values ranged from 3600 ± 200 mg/kg in uncooked Irish potato, to a low of 900 ± 12 mg/kg in uncooked sweet potato. Dasheen had values of 2250 ± 450 mg/kg while yellow yam had values of 1150 ± 50 mg/kg. The values for the cooked samples on the other hand ranged from a low of 580 ± 20 mg/kg for cooked yellow yam to a high of 3025 ± 25 mg/kg for Irish potato. Cooked sweet potato contained 650 ± 50 mg/kg while dasheen contained 2150 ± 150 mg/kg. There was no significant loss of magnesium recorded upon cooking samples of yellow yam, sweet potato or dasheen. Irish potato recorded a significant loss of this mineral

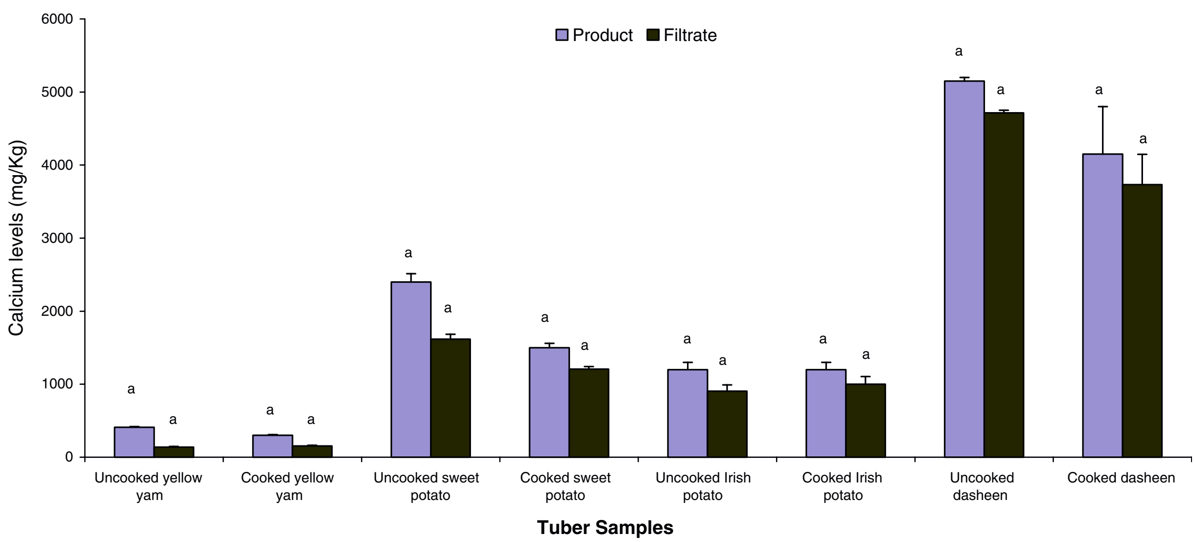

Figure 1. Calcium levels in selected tuber crops and their corresponding filtrates after *in vitro* digestion. Statistical comparisons are made between the cooked and uncooked tuber samples only. Figures that share different letter subscripts are significantly different ($P > 0.05$).

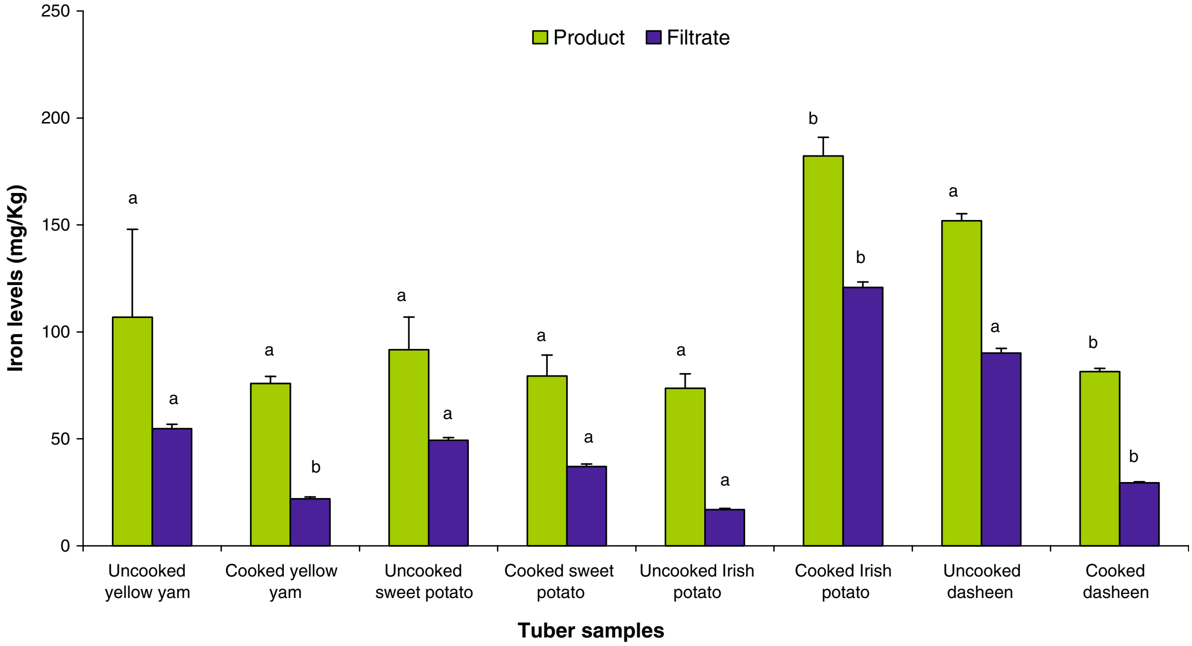

Figure 2. Iron levels in commonly consumed tuber samples and their corresponding filtrates after *in vitro* digestion. Statistical comparisons are made between the cooked and uncooked tuber samples only. Figures that share different letter subscripts are significantly different ($P > 0.05$).

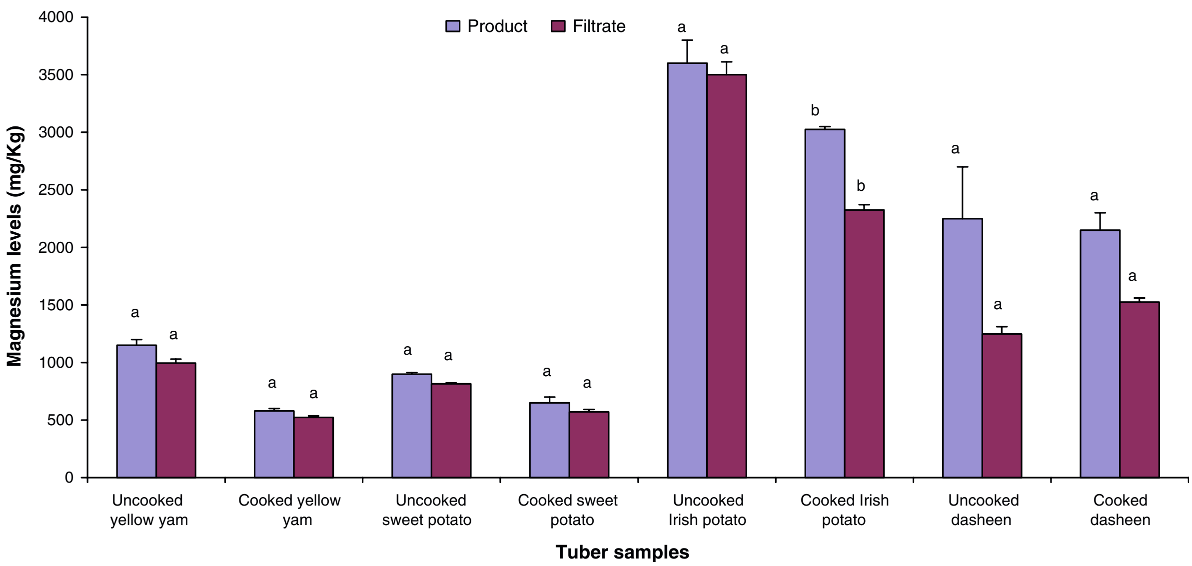

Figure 3. Magnesium levels in commonly consumed tuber samples and their corresponding filtrates after *in vitro* digestion. Statistical comparisons are made between the cooked and uncooked tuber samples only. Figures that share different letter subscripts are significantly different ($P > 0.05$).

upon cooking. Magnesium levels within the filtrate followed a similar pattern as significant reductions were only recorded for the Irish potato samples.

Discussion

The levels of the macronutrients magnesium and calcium, along with the micronutrient, iron were assessed in the following tuber crops: yellow yam, sweet potato, Irish potato and dasheen. More importantly, the extent to which these minerals are available for absorption were also assessed. Of the samples analyzed, dasheen displayed the highest levels of calcium with values of 5150 mg/kg for the cooked samples. The lowest levels of 300 mg/kg were recorded for the cooked samples of yellow yam. Cooking of Irish potato did not result in any loss of calcium as similar levels of this mineral were observed in both the cooked as well as the uncooked samples. With such appreciable levels of calcium, these tuber crops if included in the diet should be important contributors to the recommended daily allowance for Calcium (US RDA: 800–1200 mg). Overall, there was no significant loss of calcium from the samples after cooking. This method of processing is therefore suggested if there is the need to retain calcium. These experiments have shown that these tubers do not only have high levels of calcium but a large percentage of the calcium is also available for absorption.

The extent of mineral availability from the different tuber samples was assessed by *in vitro* digestion. The mineral content in the filtrates represents the soluble portion of minerals hence the portion available for absorption (Skibniewska 2002). The presence of minerals in foods is therefore no indication of its availability. The bioavailability of minerals depends on several factors including the molecular form in which it is presented for absorption and the presence of antinutritional factors. In general, it was found that samples with high overall levels of minerals displayed correspondingly high levels of minerals in the filtrate. Irish potato seems to be the best source of magnesium in terms of overall quantity and this was followed by dasheen. Yellow yam and sweet potato had similar levels with yellow yam having slightly higher quantities. All the samples recorded decreased magnesium levels after cooking. This loss was most significant in samples of Irish potato while losses in the other samples were negligible.

Cooking resulted in a reduction in the amount of iron present in samples of yellow yam, sweet potato and dasheen. This method of processing, however, had the opposite effect on Irish potato as the iron levels were increased upon cooking. Although no significant loss of total iron was recorded for yellow yam or sweet potato upon cooking, a significant loss of soluble iron was recorded for yellow yam. A significant loss of both total and soluble iron was also observed in samples of dasheen upon cooking. Surprisingly, Irish potato recorded a significant increase in both total and soluble iron upon cooking which may be beneficial but the reason for the observed increase is not clear. The anti-nutritional composition and processing method of Irish potato may be the contributing factors but this requires further detailed study. For the samples in which there was a loss of soluble iron upon cooking, careful monitoring of cooking methods is required to avoid excess loss of this essential mineral from the food during processing. This is especially important in areas where the total mineral intake may already be low and there may be a risk of iron deficiency.

The practice of boiling foods and subsequent discarding of the water may cause loss of water soluble minerals as well as other nutrients like vitamins. In a boiling procedure where the water is retained, however, as in preparing soup or a stew, the loss of these minerals will be minimized (Bradbury et al. 1987). This is, however, not practical for all tuber crops, as some may have high levels of cyanide or an acrid principle wherein special methods are required to remove the offending principle (Osagie 1998). In order to derive maximum benefits from these food crops, careful assessment of each sample is needed to determine the levels of minerals present (soluble and insoluble portions), as well as levels of antinutrient factors and the effect that processing has on altering their levels.

Overall, Irish potato displayed the highest level of minerals leading the way in magnesium and Iron levels, while having the second highest level of calcium. In terms of mineral availability, a similar trend was observed with Irish potato leading the way in the amount of soluble Magnesium and Iron while placing third with respect to the amount of soluble Calcium. The high overall level of soluble minerals in the samples indicates that they are good sources of essential minerals.

It is observed that for all the tuber crops except yellow yam, daily consumption of 500 g of sample will satisfy both the United States and United Kingdom daily requirements. RDA for Iron (US RDA 15 mg and EU RDA 14 mg). Daily consumption of 1 kg of any of the tuber crops will satisfy the daily Magnesium RDA. However, consumption of only 500 g of cooked dasheen or

Irish potato would be necessary to satisfy this requirement of 400 mg. Consumption of 1 kg of cooked sweet potato or only 300 g of dasheen per day is enough to satisfy the upper limit recommended daily allowance of Calcium (500 mg). Daily consumption of these crops in such quantities may not be practical, but the development of value added products from these tuber crops will go a far way in addressing this issue. Some of these products include baked products (cakes and puddings) or breakfast staple items, *e.g.* bammies (local bread), traditional breads or other snacks.

In conclusion, the consumption of these tuber crops in the Caribbean may not be responsible for the reported cases of iron deficiency in the region. However, the availability of minerals from these tuber crops when consumed with other foods (the usual practice in the Caribbean) needs further investigation. The data obtained in this study did not give straight increase or decrease with respect to Irish potato indicating that other factors such as the method used may be important in determining the availability of minerals in the processed food samples.

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