

Full Length Research Paper

Effect of three processing methods on some nutrient and anti-nutritional factor constituent of *Colocasia esculenta* (Amadumbe)

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Colocasia esculenta L. Schott (Amadumbe) is a major starchy food crop used in the rural areas in Kwazulu-Natal province, South Africa. Like most root crops, Amadumbe is rich in carbohydrate content with low protein and lipids. Preliminary screening of Amadumbe revealed the presence of some anti-nutrients (amylase inhibitor, trypsin inhibitor, oxalate, alkaloids, saponin, phytate and total phenols). The effect of various domestic processing (boiling, roasting and frying) on the levels of the anti-nutrients in Amadumbe tubers was investigated. A 'white' and 'purple' (local denomination) Amadumbe variety was used. Anti-nutrients were reduced (6-90%) by the domestic processing techniques. Of the three different treatments, boiling appeared to be the most effective in reducing levels of all the investigated anti-nutrients in both Amadumbe varieties. It is therefore concluded from the results of this study that the anti-nutritional factors, though present in raw tubers, should not pose a problem with regard to human consumption if the tubers are properly processed.

Key words: Anti-nutrients, processing, *Colocasia esculenta*.

INTRODUCTION

Vegetables synthesize and store certain biologically active substances named anti-nutritional factors (Bhandari and Kawabata, 2004). Anti-nutrients of plant foods like legumes (Soetan and Oyewole, 2009; Mohamed et al., 2011), cassava (Montagnac et al., 2009; Ebuehi et al., 2005), wild yam (Shajeela et al., 2011), sweet potato and potato (Olayiwola et al., 2009; Burlingame et al., 2009) have been investigated. Their presence in food give rise to a genuine concern for human health in that they prevent digestion and absorption of essential nutrients (Mohamed et al., 2011;

Offor et al., 2011). Most anti-nutritional factors are heat labile and are partially inactivated during ordinary cooking (Prathibha et al., 1995). The residual anti-nutrients can, however, be responsible for the development of serious gastric distress (Brune et al., 1989). Prolonged eating of residual anti-nutrients have also been linked to the etiology of goiter (FAO, 2013), tropical ataxic neuropathy (FAO, 2013; Sarkiyayi and Agar, 2010), inactivating digestive enzymes (Akande et al., 2010), lowering the bioavailability of nutrients (Duranti, 2006; Hotz and Gibson, 2007; Barde et al., 2012), nausea,

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bloating and vomiting (Liener, 1986).

Amadumbe (zulu for *Colocasia esculenta*) is an introduced species widely grown in the sub-tropical parts of South Africa as a subsistence crop (Makgoba, 2004; Shange, 2004). It is commonly used in rural communities in Zululand as a source of dietary starch. The tubers are processed by baking, roasting, or boiling; and the leaves are processed like spinach by boiling them for about 15 min, the leaves are also used in making salad. An active α -amylase inhibitor in Amadumbe has been isolated and characterized (McEwan et al., 2010). Little information is available on the residual levels of anti-nutrients in Amadumbe. It is therefore pertinent that this under-utilized crop be investigated for the nutritional and anti-nutritional components.

The present study examined the effects of domestic processing on the anti-nutrient levels of Amadumbe. A 'white' and 'purple' (local denomination) Amadumbe variety was used (Ferrerres et al., 2012). Domestic cooking or roasting alters the nature and bioavailability of many food constituents (Suresh et al., 2006).

MATERIALS AND METHODS

Sample collection

Purple and white varieties of Amadumbe (*Colocasia esculenta*) tubers were obtained from the local market at Esikhawini, KZN province, South Africa. Tubers were washed under tap water, peeled and cut into 1cm³ pieces. These were then divided into four portions. One portion (the unprocessed sample) was dried at 55°C for 24 h, milled into a fine powder, and stored in brown bottles until use. The other three portions were separately processed (boiled, fried and roasted).

Processing techniques

500 g of the samples were separately subjected to the following processing techniques: i) boiling: 500 g of 1 cm³ Amadumbe pieces were boiled in distilled water on a stove for 30 min; ii) frying: 500 g of 1cm³ pieces were fried in 30 ml Sunflower vegetable cooking oil for 15 min; iii) roasting: 500 g of 1 cm³ Amadumbe pieces were roasted in a baking pan in an oven for 30 min at 180°C.

The processed samples were dried at 55°C for 24 h after which they were milled into a fine powder and stored in 500 ml glass laboratory bottles until use. The samples were then screened for the presence of nutrients and anti-nutrients.

Proximate composition

Protein, moisture, carbohydrate, ash and crude fat contents were determined as described in AOAC methods (AOAC, 1984).

Determination of anti-nutrients

Trypsin inhibitor

The method of Kakade et al. (1974) was used to determine the anti-

trypsin activity. Trypsin activity was measured by using benzoyl-DL-arginine-*p*-nitroaniline (BAPNA) as substrate in the presence and absence of sample extract. *p*-Nitroanilide released was measured spectrophotometrically at 410 nm. Trypsin inhibitor activity was therefore expressed as the decrease in trypsin activity per unit weight of sample, using the formula:

$$TIA = 2.632 \cdot D \cdot At/S \text{ mg pure trypsin inhibited g}^{-1} \text{ sample}$$

D is the dilution factor, *At* is the change in absorbance and S is the amount of sample weighed out.

Amylase Inhibitor

α -Amylase and α -amylase inhibitory activities were estimated according to the method utilized by Bernfeld (1955). Amylase inhibitor extracts were mixed with amylase and incubated for 30 min at 37°C. The reaction was started by adding extract-enzyme mixture to test tubes containing buffered starch solution (2 mg starch in 20 mM phosphate buffer of pH 6.9 containing 0.4 mM NaCl) and was incubated for 20 min. This reaction was terminated by adding 3,5-dinitrosalicylic acid (DNS) reagent to the assay mixture. The assay tubes were kept in a boiling water bath for 5 min, cooled under tap water and the colour formed by maltose oxidation was measured at 530 nm. Controls without inhibitor were run simultaneously. One α -amylase unit (1UI) was defined as the amount of enzyme that will liberate 1 μ mol of maltose from the starch under the assay conditions (10 min, 37°C, pH 6.9). The amylase inhibitors activity (AIA) was determined as the percentage decrease in α -amylase activity (at the stated conditions) in the presence of Amadumbe extracts.

Total polyphenols

Total polyphenols were determined according to Prussian blue spectrophotometric method (Price and Butler, 1977). The total phenols were extracted into 2 M HCl. Timed additions were done to the extracted 1 ml sample with 0.10 M FeNH₄(SO₄)₂ and 0.008 M K₃Fe(CN)₆ to develop colour. Absorbance was measured spectrophotometrically at 720nm. The total phenol concentration was estimated from the gallic acid standard curve.

Alkaloid

Amadumbe alkaloids were detected by the method of Harborne (1973). 1 ml Amadumbe sample were covered for 4 h in 10% acetic acid in ethanol. This was filtered and extract was concentrated. Precipitation was done by adding concentrated ammonium hydroxide and then it was washed with dilute ammonium hydroxide. The alkaloid residue was dried and weighed.

Oxalate

Oxalate was determined by the method of Munro and Basir (1969). Oxalate was extracted from the sample (1:5 w/v) with 0.15% citric acid and treated with tungstophosphoric acid. Precipitated oxalate was solubilized with 1% hot diluted H₂SO₄ and titrated against KMnO₄ as equivalent to 0.3 g/100 ml of calcium oxalate.

Phytate

The colorimetric assay of phytate was performed according to

Table 1. Nutritional composition (g/100%DM) of unprocessed as well as processed Amadumbe tubers from Esikhawini local market, Zululand.

Parameter	Moisture	Ash	Crude fat	Crude proteins	Carbohydrates	
					Starch	Soluble sugar
Esikhawini white	89	4.4	0.8	5.04	28	4.0
Boiled white (BW)	88	4.4	0.78	5.04	25	3.0
Roasted white (RW)	84	3.6	1.58	6.87	27	2.0
Fried white (FW)	85	4	10.58	4.2	18	2.7
Esikhawini purple	89	3.3	0.28	4.5	25	2.0
Boiled purple (BP)	88	3.2	0	4.56	22	3.1
Roasted purple (RP)	87	4	2.52	4.36	20	2.5
Fried purple (FP)	85	3.2	15.05	3.95	15	2.0

Mehlich N^o. 1 double acid extraction for metals (Mehlich, 1953). Double acid extraction (HCl and H₂SO₄) was done on sample materials for 3 h. Samples were filtered under vacuum through Whatman N^o. 1 filter paper. Colour was developed by adding ammonium molybdate, ascorbic acid and potassium antimonytartrate and absorbance was measured at 820 nm. The concentration of phytate was calculated from its phosphorus content.

Total cyanogens

Cyanogens were assayed enzymatically by the method described by O'Brien et al. (1991). Amadumbe samples were homogenized (1:5 w/v) with orthophosphoric acid/ethanol (1:1) medium. An aliquot of extract was added to buffer A prepared from 0.1 M H₃PO₄ and Na₃PO₄, and β-glycosidase with activity of 5 EU ml⁻¹. Colorimetric procedure for total cyanogens was followed with pyridine/pyralozone reagent. Absorbance was measured at 620 nm.

Saponin

Saponin content was determined by the method of Fenwick and Oakenfull (1981). Saponin was extracted from 10 g Amadumbe for 24 h in a reflux with acetone. Re-extraction with methanol in the Soxhlet apparatus was done for another 24 h. Colour development was done with vanillin in ethanol and sulphuric acid. Absorbance was measured at 500nm.

RESULTS

Proximate composition

The data for the processed and the unprocessed samples are presented in Table 1. Water content was high in the investigated starchy staples which on average ranges between 84-89%. The ash content was between 3.2 and 5.4% of the dry weight elements. The lipid content for these unprocessed corms ranged between 0.73 and 1.54%. The crude fat content for the fried Amadumbe tubers was understandably higher (10.58 and 15.05% respectively), than the mean crude fat value for the boiled and roasted samples (1.15%) as well as for the unprocessed samples (0.9%). The chemical composition

of the unprocessed *C. esculenta* tubers reveals high levels of starch (28-16%), the predominant component of dry matter. Processing decreased the total carbohydrate content of the Amadumbe tubers.

Anti-nutritional factors

The levels of anti-nutritional factors in the locally grown Amadumbe's are also very important in the assessment of their nutritional status. The results for unprocessed and processed Amadumbe tubers are presented in Table 2. Amadumbe was found to contain α-amylase and trypsin inhibitor, total phenols, alkaloids, oxalates, phytates, cyanogens and saponin.

The results reveal that there was a significant reduction in the anti-nutritional compounds (except for oxalate) during domestic processing. The highest losses of oxalate (0.13 mg.g⁻¹ decreased to 0.06 mg.g⁻¹ – 54%) occurred with boiling the white Amadumbe sample and there was an increase in oxalate content with roasting and frying. The highest losses of most of the anti-nutrients occurred with boiling the Amadumbe samples in water.

DISCUSSION

In general, variations were observed in the proximate composition values obtained between the two varieties as well as the processed samples. Such variations between the two varieties have been ascribed to differences in the genetic background as well as climate, season, and the agronomic factors (Onwueme, 1982). Apart from the soluble sugar, all the proximate indices measured in the Amadumbe corms were similar to most other taro or cocoyam species (Bradbury and Holloway, 1988; Pérez et al., 1998; Sefa-Dedeh and Agyir-Sackey, 2004). For each Amadumbe variety, processing methods showed no significant effects on the moisture, ash and protein contents. Fried tubers had a higher level of fat (10.58 and 15.05% respectively) than raw or cooked tubers in this

Table 2. The levels of some anti-nutritional factors in processed and unprocessed tubers (*Colocasia esculenta*) from Zululand.

Anti-nutrients (mg.g ⁻¹)	Esikhawini		Boiled		Roasted		Fried	
	White	Purple	White	Purple	White	Purple	White	Purple
Trypsin Inhibitor	19.7	16.5	0 (100)	0 (100)	0 (100)	0 (100)	0 (100)	0(100)
Amylase Inhibitor	21	25	11 (48)	9 (64)	5 (76)	7 (72)	6 (71)	6 (76)
Total phenols	11.5	13.0	7.1 (38)	9.8 (24)	10.0 (13)	12.2 (6)	10.8 (6)	14.0 (0)
Alkaloids	0.19	0.18	0.04 (79)	0.06 (67)	0.04 (79)	0.08 (56)	0.13 (32)	0.04 (78)
Oxalates	0.13	0.10	0.06 (54)	0.06 (40)	0.14 (0)	0.21 (0)	0.14 (0)	0.1 (0)
Phytates	3.1	2.8	1.3	1.4	1.1	1.8	0.8	0.8
Cyanogens	0.012	0.025	0.001 (92)	0.008 (68)	0.003 (75)	0.003 (88)	0.002 (83)	0.006 (76)
Saponin	0.136	0.145	0.056	0.052	0.079	0.10	0.123	0.995

^aFigures in parentheses indicate the percentage decrease over the values of the corresponding raw tuber.

investigation and the changes in fat content of the fried products were due to fat being absorbed from the frying medium (oil). The differences in processing may therefore be due to variations in other components (Afoakwa and Sefa-Dedeh, 2001). The high moisture and carbohydrate content and the low amounts of fat and protein are typical of most root crops (FAO, 2013). Tuber and root crops are generally rich in carbohydrates, and Amadumbe are mainly consumed as a cheap but good source of carbohydrate (Alcantara et al., 2013).

The nutritional importance of any food product depends not only on the nutrient composition but also on the presence of anti-nutritional factors. The higher the concentration of these metabolites the more dangerous they become to health. The essence of estimating the concentrations of these secondary plant metabolites is to establish the amount of anti-nutrient levels in Amadumbe's consumed.

When the values were compared with other works for taro, cocoyam and yam, the oxalate (Lewu, 2010; Offor et al., 2011; Alcantara et al., 2013) and cyanogen (FAO, 2013; Amanze, 2009) content were observed to be low, while total phenols (Offor et al., 2011; Alcantara et al., 2013) and phytate (Lewu, 2010; Polycarp et al., 2012; Alcantara et al., 2013) were considerably higher. It was difficult to compare the amylase inhibitor activities for taro, cocoyam and other tubers reported by different investigators, mainly because of the difference in method used. The initial trypsin inhibitor level in the Amadumbe tubers were completely inactivated with all three domestic processing methods. A similar observation of inactivation with cooking of the trypsin inhibitors of taro was reported (Sasi Kiran and Padmaja, 2003). The drastic reduction of trypsin inhibitor activity (TIA) values on cooking could possibly be due to high heat treatments during cooking of tubers and the well established heat labile nature of trypsin inhibitor (Prathibha et al., 1995; Bradbury et al., 2006). The reduction of TIA is expected to enhance the proteins digestibility of the Amadumbe tubers. The processing methods reduced on average 48-76% of the initial α -amylase inhibitors. It is apparent that these

inhibitors (α -amylase) were more heat stable than the trypsin inhibitors. It has been reported that amylase inhibitors persist through cooking temperatures despite their susceptibility to heat inactivation (Liener and Kakade, 1980).

The highest losses of oxalate (0.13 mg.g⁻¹ decreased to 0.06 mg.g⁻¹; 54%) occurred with boiling the white Amadumbe sample (Table 2). It is apparent that boiling caused considerable cell rupture and facilitated the leakage of soluble oxalate into cooking water (Albihn and Savage, 2001; Luma and Katongole, 2011). When the samples were roasted and fried, there was an increase in oxalate content. This apparent increase could be related to the relative increase in dry matter as Amadumbe is roasted and fried. Similar cooking studies on oca (*Oxalis tuberosa*) showed that boiling considerably reduced the oxalate concentration in the whole tuber, while baking increased the concentration of soluble oxalates in the cooked tissue (Albihn and Savage, 2001). The phytate content of the investigated tubers got reduced up to 74% when processed. The apparent decrease in content of phytic acid during cooking may be partly due to leaching into the cooking medium or degradation by heat or the formation of insoluble complexes between phytate and other components such as phytate-protein and phytate-protein-mineral complexes (Siddhuraju and Becker, 2001; Mohamed et al., 2011). Reduction of phytate is expected to enhance the bioavailability of proteins and dietary minerals of the Amadumbe tubers. The processing techniques were also highly effective in substantially reducing the cyanogens to low levels (0.1-0.8 mg HCN equivalent/100 g). Boiling for 30 min were found to be highly effective in reducing the HCN by up to 92 and 68% respectively. The reduction of hydrogen cyanide due to boiling may be as a result of the fact that free cyanide and bond cyanide are both water soluble and hence may be leached out during boiling (Udensi et al., 2007).

This study shows that the tuber of *C. esculenta*, (Amadumbe), could be used more as food material for human consumption, judging from the high carbohydrate, adequate protein and low lipid content. The results

indicate that the studied anti-nutritional factors, though showing a significant concentration in raw tubers, should not pose a problem in human consumption if the tubers are properly processed. The reduction of these anti-nutrient levels on processing is expected to enhance the nutritional value of these Amadumbe tubers.

Consumption of such properly cooked Amadumbe tubers may serve an additional dietary carbohydrate source for the rural people living in Zululand. However, the reductions in anti-nutrients which constitute the undesirable properties may imply possible reduction in the levels of nutrients and mineral elements. It is believed that supplementation from other sources such as vegetables usually eaten with the cooked Amadumbe, could improve the levels of these elements.

Conflict of Interests

The author(s) have not declared any conflict of interests.

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