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Effects of cooking on the nutrient and antinutrient contents of yam tubers (*Dioscorea alata* and *Dioscorea esculenta*)

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Effects of three methods of cooking, namely boiling, steaming and baking, on the nutrient and antinutrient contents of tubers of *Dioscorea alata* and *D. esculenta* were investigated. Crude protein contents of the tubers tended to decrease with cooking, but the differences were not statistically significant. Crude fat, crude fibre, starch and total sugar contents were unaffected by cooking. Water-soluble minerals leached out during boiling, thus causing a reduction in the ash content of boiled tubers. All cooking methods lowered the vitamin C content of the tubers.

Phytate contents were unaffected, whereas total oxalate contents were significantly lowered by the cooking methods employed. The loss of oxalates was greater with boiling (40–50%) compared to steaming (20–25%) and baking (12–15%).

INTRODUCTION

Yams (genus *Dioscorea*) play a significant role in the nutrition of millions of people in Africa, Asia and Oceania. In Sri Lanka, yams are grown in all agro-climatic zones and are favoured complementary foods. Yam tubers are prepared in the same way as potatoes. They are boiled, steamed or baked. Information is needed about the compositional changes associated with different methods of cooking to allow optimum nutrient retention. A study of the changes that result from cooking in the nutrient composition of *D. alata* tubers has been recently reported (Bradbury *et al.*, 1988). In the present investigation, the effects of three methods of cooking, viz. boiling, steaming and baking, on the nutrient, phytate and oxalate contents of *D. alata* and *D. esculenta* tubers are evaluated.

MATERIALS AND METHODS

Fresh tubers of six cultivars of *D. alata* (*Ini ala, Kahata ala, Kombuwalli, Raja ala, Rata ala* and *Thambala*) and three cultivars of *D. esculenta* (*Katu ala, Kukul ala* and *Siru valli*) were obtained, immediately after harvest, from the germplasm evaluation unit of the University Research Farm. About 1 kg of tuber samples of each cultivar were obtained, washed free of dirt, peeled, cut into pieces of 40–50 g and subjected to one of the following cooking methods; the experiment was repeated three times.

Boiling: water was added to the cut pieces at the ratio of 1:1 (w/w) and the mixture cooked in a closed stainless steel vessel for 30 min. Water was discarded after boiling.

Steaming: cut pieces were steamed for 15 min in the lower pan of a pressure cooker (Prestige, Bombay, India).

Baking: pieces were wrapped in aluminium foil and baked in an air circulating oven (Fisher Laboratory, Pensylvania, USA) at 180°C for 45 min.

The above procedures were designed to simulate the domestic cooking methods generally employed in Sri Lanka to prepare yams for the table. After cooking, the samples were allowed to dry at room temperature, mashed to ensure homogeneity and stored in plastic bags at –4°C for subsequent analyses.

Proximate analyses were carried out according to standard procedures (AOAC, 1975). The determination of starch was based on the method of Pucher *et al.* (1948) with corn starch as the standard. Soluble sugars in the yam flour were extracted using the AOAC (1975)

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Table 1. Effects of cooking on the nutrient and antinutrient contents of *D. alata* tubers*

	Fresh tuber	Boiled	Steamed	Baked
Dry matter (%)	26·1 ± 2·9^{b}	19·4 ± 3·1^{a}	27·9 ± 3·8^{b,c}	31·2 ± 3·3^{c}
Crude protein (% DM)	7·4 ± 0·9	6·7 ± 0·6	6·7 ± 0·8	6·6 ± 0·8
	(1·9)†	(1·3)	(1·9)	(2·0)
Crude fat (% DM)	1·0 ± 0·1	1·0 ± 0·1	1·0 ± 0·1	1·0 ± 0·05
	(0·3)	(0·2)	(0·3)	(0·3)
Crude fibre (% DM)	1·5 ± 0·3	1·5 ± 0·1	1·5 ± 0·1	1·5 ± 0·1
	(0·4)	(0·3)	(0·4)	(0·5)
Ash (% DM)	3·4 ± 0·2	2·6 ± 0·3	3·4 ± 0·2	3·1 ± 0·1
	(0·9)	(0·5)	(0·9)	(1·0)
Starch (% DM)	78·7 ± 3·1	78·4 ± 2·9	78·5 ± 3·4	77·4 ± 3·8
	(20·5)	(15·2)	(21·9)	(24·1)
Total sugars (% DM)	1·1 ± 0·1	1·3 ± 0·2	1·3 ± 0·1	1·3 ± 0·1
	(0·3)	(0·2)	(0·4)	(0·4)
Vitamin C (mg/100 g fresh weight)	18·4 ± 3·9^{a}	9·1 ± 0·8^{b}	11·3 ± 2·2^{b}	9·3 ± 1·7^{b}
Phytic acid (mg/100 g DM)	134 ± 47	116 ± 34	121 ± 37	122 ± 38
	(35)	(22·5)	(34)	(38)
Total oxalate (mg/100 g DM)	592 ± 116^{a}	337 ± 94^{c}	469 ± 70^{b}	498 ± 74^{b}
	(154)	(65)	(131)	(155)
Mineral (mg/100 g DM):				
K	1600 ± 299^{a}	1410 ± 297^{b}	1535 ± 307^{a}	1542 ± 299^{a}
	(418)	(273)	(428)	(481)
Na	68 ± 10^{a}	43 ± 9^{b}	61 ± 10^{a}	65 ± 8^{a}
	(18)	(8)	(17)	(20)
Ca	67 ± 8^{a}	53 ± 5^{b}	61 ± 5^{a}	63 ± 6^{a}
	(17)	(10)	(17)	(20)
P	171 ± 14^{a}	141 ± 8^{b}	156 ± 8^{a,b}	165 ± 8^{a}
	(45)	(27)	(93)	(51)
Mg	70 ± 3^{a}	60 ± 2^{b}	64 ± 4^{a,b}	64 ± 3^{a,b}
	(18)	(12)	(18)	(20)
Fe	10·5 ± 0·3^{a}	8·9 ± 0·4^{b}	9·8 ± 0·6^{a,b}	9·7 ± 0·5^{a,b}
	(3·0)	(1·7)	(2·7)	(3·0)
Cu	6·6 ± 1·1	6·2 ± 0·3	6·4 ± 0·2	6·3 ± 0·2
	(2·0)	(1·2)	(1·8)	(2·0)
Mn	3·5 ± 0·3	3·4 ± 0·3	3·4 ± 0·3	3·4 ± 0·3
	(0·9)	(0·66)	(0·9)	(1·0)
Zn	4·0 ± 0·3	3·9 ± 0·3	3·7 ± 0·4	3·7 ± 0·3
	(1·0)	(0·8)	(1·0)	(1·1)

*Values represent means ± SD of 18 samples (six cultivars and three samples per cultivar).
†Values in parentheses refer to contents per 100 g edible portion.
^{a,b,c}Means followed by different superscripts within a row are significantly different ($P < 0·05$).

procedure and quantified according to the procedure of Dubois *et al.* (1956). Vitamin C contents were determined using the AOAC (1975) procedure. Phytic acid was estimated by the colorimetric method of Wheeler and Ferrel (1971). Oxalate contents were determined by the method of Abaza *et al.* (1968).

Mineral analyses were carried out on samples digested with nitric acid. Phosphorus was determined colorimetrically using potassium dihydrogen phosphate as the standard (Anon., 1979). All other minerals were determined using an atomic absorption spectrophotometer (Perkin Elmer 2380), following the methods described by Chapman and Pratt (1961). All chemical determinations were done in triplicate. Data were subjected to analysis of variance and, where appropriate, means were compared using least significant difference (SAS, 1982).

RESULTS AND DISCUSSION

The compositional changes during cooking treatments were remarkably similar in the tubers of different cultivars of *D. alata* as well as *D. esculenta*. For this reason, data from all *D. alata* and *D. esculenta* cultivars, respectively, were pooled, reanalysed and presented together.

Data summarized in Tables 1 and 2 show that tubers of both yam species responded in a somewhat similar manner to treatments. Dry matter contents of tubers were significantly ($P < 0·05$) influenced by cooking. Significant decreases in dry matter contents were observed in boiled tubers. Dry matter levels of the tubers were unaffected by steaming, but tended to increase upon baking. These observations are consistent with the inherent nature of the cooking treatments.

Table 2. Effects of cooking on the nutrient and antinutrient contents of *D. esculenta* tubers*

	Fresh tuber	Boiled	Steamed	Baked
Dry matter (%)	31·7 ± 0·5^{b}	27·2 ± 1·4^{a}	33·2 ± 1·3^{c}	38·0 ± 2·1^{d}
Crude protein (% DM)	7·0 ± 1·1 (2·2)†	6·4 ± 0·5 (1·7)	6·5 ± 0·5 (2·1)	6·4 ± 0·8 (2·4)
Crude fat (% DM)	1·0 ± 0·1 (0·3)	0·9 ± 0·1 (0·2)	1·0 ± 0·1 (0·3)	1·0 ± 0·1 (0·4)
Crude fibre (% DM)	1·7 ± 0·2 (0·5)	1·7 ± 0·1 (0·5)	1·7 ± 0·1 (0·6)	1·7 ± 0·2 (0·6)
Ash (% DM)	3·1 ± 0·1^{a} (1·0)	2·1 ± 0·2^{b} (0·6)	2·8 ± 0·1^{a} (0·9)	2·9 ± 0·1^{a} (1·1)
Starch (% DM)	82·8 ± 4·5 (26·2)	80·9 ± 3·5 (22·0)	81·7 ± 2·8 (27·1)	82·3 ± 2·1 (31·3)
Total sugars (% DM)	1·5 ± 0·1 (0·5)	1·7 ± 0·1 (0·5)	1·6 ± 0·1 (0·5)	1·6 ± 0·1 (0·6)
Vitamin C (mg/100 g fresh weight)	16·7 ± 1·3^{a}	8·3 ± 0·8^{b}	9·3 ± 0·4^{b}	9·5 ± 2·1^{b}
Phytic acid (mg/100 g DM)	114 ± 12 (36)	109 ± 14 (30)	105 ± 20 (35)	110 ± 9 (42)
Total oxalate (mg/100 g DM)	511 ± 48^{a} (162)	260 ± 30^{d} (71)	396 ± 8^{b} (131)	448 ± 21^{c} (170)
Mineral (mg/100 g DM)				
K	1835 ± 68^{a} (582)	1360 ± 101^{c} (370)	1532 ± 83^{b} (509)	1603 ± 110^{a,b} (609)
Na	59 ± 6^{a} (19)	39 ± 5^{b} (11)	58 ± 4^{a} (19)	58 ± 4^{a} (22)
Ca	78 ± 4^{a} (25)	63 ± 8^{c} (17)	68 ± 2^{bc} (23)	70 ± 8^{bc} (27)
P	117 ± 9^{a} (37)	98 ± 6^{b} (27)	101 ± 8^{b} (33)	102 ± 8^{b} (39)
Mg	68 ± 4^{a} (21)	58 ± 5^{b} (16)	63 ± 9^{ab} (21)	60 ± 3^{ab} (23)
Fe	9·3 ± 0·5 (3·0)	8·8 ± 0·7 (2·4)	9·1 ± 0·7 (3·0)	9·1 ± 0·4 (3·5)
Cu	6·1 ± 0·2 (2·0)	6·0 ± 0·1 (1·6)	6·1 ± 0·3 (2·0)	6·0 ± 0·2 (2·3)
Mn	4·2 ± 0·2 (1·3)	4·0 ± 0·2 (1·1)	4·2 ± 0·2 (1·4)	4·1 ± 0·3 (1·6)
Zn	3·9 ± 0·5 (1·2)	3·5 ± 0·6 (0·9)	3·5 ± 0·2 (1·2)	3·6 ± 0·4 (1·4)

*Values represent means ± SD of nine samples (three cultivars and three samples per cultivar).
†Values in parentheses refer to contents per 100 g edible portion.
^{a,b,c}Means followed by different superscripts within a row are significantly different ($P < 0·05$).

Increased moisture content in boiled tubers is of direct nutritional relevance, because of its effects in increasing the bulkiness and in lowering the nutrient content per unit edible portion.

Crude protein contents of the tubers decreased on all treatments, but the differences were not statistically significant. Crude fibre, crude fat, starch and sugar contents were unaffected by cooking treatments. Somewhat similar findings have been reported by Bradbury *et al.* (1988). Their results, however, showed substantial increases in the dietary fibre content during cooking and these were attributed to the formation of starch resistant to enzymic action.

Significant ($P < 0·05$) reductions in the ash content were observed in boiled tubers. This is consistent with the leaching out of minerals, particularly of K, Na, Ca, P and Mg. Similar losses upon boiling of yam tubers have been reported by Bell (1984). Retention of minerals was greater with baking and steaming.

As anticipated, cooking treatments resulted in a significant ($P < 0·05$) decrease in the vitamin C content of the tubers. The three methods of cooking caused similar magnitudes of losses. In contrast, Bradbury and Singh (1986) observed a greater loss of vitamin C during baking compared to boiling or steaming.

Phytic acid not only lowers the availability of P to humans, but also adversely affects the utilization of Ca, Zn, Fe and Mg through the formation of insoluble complexes (Oberleas, 1973). Cooking has been reported to lower the phytate levels in grain legumes (Kumar *et al.*, 1978; Iyer *et al.*, 1980; Tabekhia & Luh, 1980) and cereals (Toma & Tabekhia, 1979). In contrast, the present authors' data show that phytate contents in yam tubers were unaffected by the cooking methods

employed. It has been suggested that the phytate removal by cooking is low when it is associated with proteins and/or cations (Reddy *et al.*, 1982). This may be the case in yam tubers. However, the phytate contents of yams are much lower than the values of 400–2060 mg/100 g reported for cereals and grain legumes (Reddy *et al.*, 1982) and should not be a nutritional concern even when yams are consumed as the staple food.

Oxalate contents were significantly ($P < 0.05$) lowered by the cooking treatments. Loss of oxalate was greater with boiling (40–50%) compared to steaming (20–25%) and baking (12–15%). The greater losses during boiling are consistent with the authors' earlier finding that 50–70% of the oxalates present in tubers are in a water-soluble form (Wanasundera, 1990). These observations are of interest because of the alleged adverse effect of oxalate on calcium utilization (Libert & Franceschi, 1987).

The overall results indicate that the effects of boiling, steaming and baking on the nutrient contents of yam tubers were somewhat similar. Boiled tubers, however, could be expected to have a lower nutrient content per unit edible portion because of their high moisture levels. Mineral retention is also inferior on boiling compared to steaming and baking. This is due to the solubilization of minerals in water during boiling, which are removed when the water is discarded. This solubilization effect, however, becomes a nutritional advantage as far as removal of oxalate is concerned.

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