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Nutritional assessment of yam (*Dioscorea alata*) tubers

J.P.D. WANASUNDERA & G. RAVINDRAN*
Department of Food Science and Technology, University of Peradeniya, Sri Lanka (author for correspondence)*

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Abstract. The nutrient and antinutrient components of tubers from seven cultivars of *Dioscorea alata* were determined. The average crude protein content of *D. alata* tubers was 7.4%. Starch (75.6–84.3%) was the predominant fraction of the tuber dry matter. Significant differences in crude protein and starch contents were observed among cultivars. Vitamin C content of the yam tubers ranged from 13.0 to 24.7 mg/100 g fresh weight. The results showed yams to be reasonably good sources of minerals. Phytic acid contents of the yams were low, with values ranging from 58.6 to 198.0 mg/100 g dry matter. Total oxalate levels in yam tubers were found to be in the range of 486–781 mg/100 g dry matter, but may not constitute a nutritional concern since 50–75% of the oxalates were in the water-soluble form. The overall results are suggestive of the nutritional superiority of yams compared to other tropical root crops.

Introduction

The underground and aerial tubers of yam (genus *Dioscorea*) are one of the important sources of carbohydrates in some regions of the tropics. Of the ten economically important species within genus *Dioscorea* [1], *D. alata* is popular in Sri Lanka. It is grown in all ecological zones of the country. Despite an increasing interest on this tuber crop, published data on the nutrient composition of locally grown yams is scanty. As a part of work on minor carbohydrate sources that is being carried out in our laboratory, a study of the nutritional potential of yams was undertaken. Seven cultivars of *D. alata* were evaluated.

Materials and methods

Materials. Fresh tubers of the yam cultivars were obtained from the germplasm evaluation unit of the University Research Farm. The local names and tuber characteristics of the cultivars evaluated are presented in Table 1. Undamaged tubers of uniform size were selected from each cultivar immediately after the harvest and cleaned free of dirt. The tubers were sliced, dried in an Unitherm oven at 60 °C for 48 hours and ground in a Wiley mill to pass 60-mesh. Ground samples were stored in airtight plastic containers at room temperature until used.

Table 1. Local names and some characteristics of cultivars of *D. alata* evaluated in the present study*

Cultivar	Length of crop (months)	Mean tuber weight (kg)	Color of flesh
Ini ala	9–10	1.2–4.8	light purple or white
Kahata ala	9–10	9.3–20	yellowish white and pink
Kombuwalli	9–10	6.2–7.7	pale yellow
Raja ala	9–10	5.5–7.0	purplish red
Rata ala	9–10	2.2–6.0	white or orange yellow
Thambala	9–10	1.4–6.5	light orange yellow
Hingurala	9–10	3.0–5.2	yellowish white

* Source: Harischandra [24].

Nutrient analysis. All chemical determinations were carried out in triplicates. Moisture, Kjeldahl nitrogen, crude fat, crude fiber and ash contents were determined according to standard AOAC procedures [2]. Crude protein content was calculated by multiplying the nitrogen content by a factor of 6.25. The determination of starch as based on the method of Pucher et al. [3] which involved extraction of starch with perchloric acid, separation of starch as the iodine complex and decomposition of the complex with alkali and measurement of starch by the phenol-sulphuric acid method [4]. A 92% recovery of starch as obtained with corn starch, used as the standard. Soluble sugars were extracted from the yam flour with 85% ethanol as described in AOAC [2] and quantified by the phenol-sulphuric acid method [4] against glucose (Sigma Chemicals, USA) as the standard. Total energy contents were calculated using the following formula [5].

$$\text{Total energy (kcal/100 g)} = 17\text{B} + 38\text{C} + 17\text{E} + 16\text{F}/4.186,$$

where B = % crude protein, C = % crude fat, E = % starch and F = % total sugars. Vitamin C contents of fresh tuber samples were extracted with 4% (w/v) metaphosphoric acid and aliquots of the filtrate were analyzed colorimetrically with the 2,6-dichlorophenol-indophenol method [6]. Phosphorus was determined colorimetrically using potassium dihydrogen phosphate as the standard [7]. All the other minerals were analysed with Atomic Absorption Spectrophotometer (Perkin Elmer 2380) according to the method described by Chapman & Pratt [8].

Analysis of antinutrients. Phytic acid contents were determined by the procedure of Wheeler & Ferrel [9]. Total and water-soluble oxalate contents were determined by the methods described by Abaza et al. [10].

Statistical analysis. The data from *D. alata* cultivars were subjected to analysis of variance and, where F values were significant, cultivar means were compared using the Least Significant Difference test [11].

Results and discussion

The nutritional composition of tubers of *D. alata* are presented in Table 2. The average crude protein content of the tubers was 7.4%. The crude protein contents tended ($p < 0.10$) to differ among the different cultivars with values ranging from 6.7 to 7.9%. The values obtained for *D. alata* cultivars fall within the range of 4.3–8.5% reported for samples from South Pacific by Bradbury & Holloway [5]. The crude fat, crude fibre and ash contents were remarkably similar among the cultivars.

The protein contents of yam tubers, in general, are higher than those reported for other tropical roots, including cassava, sweet potato and taro [1, 12, 13]. The higher protein content of yams highlight their nutritional superiority as a staple food. Yam proteins are also reported to have a better amino acid balance compared to other tropical roots [14–16].

Starch was the predominant fraction of the dry matter of yam tubers (Table 2). The average starch content of *D. alata* tubers were 79.5%. Significant ($p < 0.05$) differences were observed among *D. alata* cultivars with regard to starch contents. *Kombuwalli*, *Raja ala* and *Hingurala* had higher starch contents compared to other cultivars. Soluble sugar contents of the yam cultivars were low (less than 1.5%). Slightly higher sugar contents (2–4%) have been reported by Bradbury [12]. As expected from their high starch and low fibre contents, the total energy contained in the yam dry matter was high. The energy contents (353–383 kcal/100 g) were similar to those reported for other tropical roots [13].

Vitamin C contents of the yam tubers were determined to be in the range of 13.0–24.7 mg/100 g fresh weight. Our values are comparable to other published reports [17, 18]. The vitamin C content of *Raja ala* could not be estimated because of the interference of the pigments in the flesh with reagent in the analytical method employed in our study.

Potassium was the major mineral present in yam tubers (Table 3). The data showed that yams are moderately good sources of minerals. For all minerals, yams, on average, are richer than cassava and sweet potato [13]. The calcium and phosphorus contents of our samples were higher than those reported for Nigerian samples by Egbe & Treche [19] and Ologhobo [20]. This discrepancy may be due to both cultivar and environmental differences [12]. In the present study, significant ($p < 0.05$) cultivar differences were observed in the levels of potassium, sodium, phosphorus, calcium and magnesium. The variations observed may be considered to largely reflect the cultivar effects, since all samples were obtained from the same cropping area subjected to similar agronomic practices.

The determinations of phytate and oxalate were of interest because of their alleged adverse effects on mineral bioavailability [21, 22]. The phytic acid contents of yams were low, with values ranging from 58.6 to 198.0 mg/100 g dry matter (Table 4). No comparable data on the phytate content of yams or any other tropical root are available. The values of yams are much lower than the values of 400–2060 mg/100 g reported for cereals and grain legumes [22]

Table 2. Nutritional composition of tubers of different cultivars of *D. alata**

Cultivar	Moisture	% Dry weight basis						Total energy (kcal/100 g)	Vitamin C (mg/100 g)
		Crude protein	Crude fat	Crude fiber	Ash	Starch	Soluble sugar		
Ini ala	73.1	7.9	1.1	1.5	3.0	75.6	1.1	353	15.8
Kahata ala	71.0	7.0	1.2	1.2	3.7	77.1	1.1	369	19.9
Kombuwalli	74.8	6.7	1.0	1.8	3.8	82.8	1.2	380	13.0
Raja ala	69.9	7.4	1.0	1.4	2.8	83.3	1.3	383	ND
Rata ala	77.1	7.9	1.0	1.6	3.6	76.5	1.2	355	18.5
Thambala	77.5	7.5	1.0	1.6	3.6	77.1	0.9	357	24.7
Hingurala	65.5	7.3	1.0	1.6	3.0	84.3	1.5	357	15.8
Mean	72.7	7.4	1.0	1.5	3.4	79.5	1.2	365	18.0
±SD	±4.0	±0.4	±0.1	±0.2	±0.4	±3.4	±0.1	±11.6	±3.7

* Values are mean of three samples, each determined in triplicates.

Table 3. Mineral composition of tubers of different cultivars of *D. alata* (mg/100 g dry matter)*

Cultivar	K	Na	P	Ca	Mg	Cu	Fe	Mn	Zn
Ini ala	1744	64.3	178	65.1	71.7	6.6	10.3	3.3	4.3
Kahata ala	1824	61.3	194	67.3	69.9	6.4	10.8	3.2	4.3
Kombuwalli	2016	78.7	155	72.1	74.6	6.5	10.2	3.9	4.2
Raja ala	1291	68.7	149	72.8	64.0	6.3	10.4	3.7	3.4
Rata ala	1157	82.7	174	62.5	71.2	6.9	10.9	3.1	4.0
Thambala	1563	52.0	171	62.6	71.3	6.9	10.1	3.7	3.6
Hingurala	1746	58.7	117	78.0	64.7	6.5	9.9	4.3	3.7
Mean	1620	66.6	163	68.6	69.6	6.6	10.4	3.6	3.9
±SD	±281.7	±10.1	±23.1	±5.4	±3.6	±0.2	±0.3	±0.4	±0.4

* Values are mean of three samples, each determined in triplicates.

Table 4. Phytic acid and oxalate contents of tubers of different cultivars of *D. alata* (dry matter basis)

Cultivar	Phytic acid (mg/100 g)	Phytin P as % of total P	Oxalates (mg/100 g)	
			Water-soluble	Total
Ini ala	135	21.4	334	486
Kahata ala	184	26.7	486	636
Kombuwalli	198	35.9	318	627
Raja ala	131	24.8	301	483
Rata ala	96.2	16.6	557	781
Thambala	58.6	9.7	422	576
Hingurala	117	28.3	262	510
Mean	131	23.3	383	585
±SD	±45	±7.8	±100	±99

and do not appear to be unacceptably high. However, phytic acid P contributed 9.7–35.9% of the total P found in the different cultivars, suggesting low P availability in some cultivars.

Table 4 shows a wide variation in the oxalate contents among different cultivars of yams. Published data on the oxalate contents of tropical roots are limited. Our values are higher than those reported for yams from the South Pacific, but compare well with those for sweet potato and taro from the same region [5, 12]. These oxalate levels do not pose a hazard, especially since 50–75% of the oxalates are present in water-soluble form. Water soluble oxalates are known to leach out during cooking in water [21] and can be removed by discarding the water.

The present findings indicate that the different cultivars of *D. alata* have a similar nutritional profile. This profile, in particular the protein content, makes them nutritionally more desirable to other tropical roots.

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