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Nutrient and anti-nutrient components of some tropical leafy vegetables

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Several leafy vegetables species (n = 17) found in Nigeria were analysed for their proximate chemical composition, mineral constituents, energy values, phytin and oxalate content in the fresh and air-dried material. The dry vegetables contained, on average, 19·3 g/100 g crude protein (CP), 15·3 g/100 g crude fibre (CF), 12·7 g/100 g ether extract (EE), 17·4 g/100 g ash and 89·9 g/100 g dry matter (DM) while the fresh counterparts contained, on average, 4·2, 3·2, 0·6, 7·3 and 17·6 g/100 g CP, CF, EE, ash and DM, respectively. Marked variations were observed in the proximate compositions of all the vegetables analysed as indicated by the high coefficients of variation. Potassium, sodium, calcium and phosphorus were the most abundant minerals in the dry samples with mean values of 3·7, 3·8, 2·5 and 1·2 g/100 g, respectively. Similarly, mean values of 4·4, 6·0, 0·9 and 0·8 g/100 g, respectively, were recorded for potassium, sodium, calcium and phosphorus in the fresh samples. Copper was the least abundant mineral in both the fresh and the air-dried samples. The mean energy value was 2787 kcal/kg with a range of 2192 kcal/kg in *Amaranthus hybridus* to 3732 kcal/kg in *Manihot esculentus*. The dry vegetables generally had higher phytate and oxalate values than the fresh ones. There were distinct familial differences in these anti-nutrient constituents as indicated by the high coefficients of variation of 39·5 and 88·9% for phytate and oxalate, respectively. The nutritive potentials of the vegetables are highlighted. Dietary implications of the anti-nutrients are also discussed, and the need to develop food/feed safe programmes involving these inherent factors emphasised.

INTRODUCTION

Several vegetables species abound in Nigeria which are utilised either as condiments or spices in human diets, or as supplementary feeds to livestock such as rabbits, poultry, swine and cattle. These vegetables are harvested at all stages of growth and fed either processed, semi-processed or fresh to man while they are usually offered fresh to livestock. However, the presence of inherent toxic factors or anti-nutritional components in plants has been implicated (Liener, 1969; Nwokolo & Bragg, 1977; Lewis & Fenwick, 1987) as one of the variables affecting the nutritional value of foods and feeds. Although these factors are usually present in trace amounts, they do have profound effects on their nutritional quality.

The upsurge in the consumption of these vegetables in many Nigerian homes due, perhaps, to the high cost of meat, indicates a need for a comprehensive list of nutritional and anti-nutritional characteristics. While most studies (especially on anti-nutritional factors) relate to their presence in European and North American species, it is conceivable that the presence of these compounds and their resultant effects on human health, are of more importance in the diets of the less well developed countries (LDCs). In these countries, the diets may be less varied and any physiological effects caused by these compounds may exacerbate existing problems of malnutrition and/or undernutrition.

In the present study, data are presented on several tropical leafy vegetables under conditions in which they are usually consumed (i.e. fresh or dry). It is envisaged that such results could contribute significantly to the development of food/feed safety programmes involving these inherent anti-nutritional factors.

MATERIALS AND METHODS

The vegetables analysed were *Manihot esculenta, Talinum triangulare, Crassocephalum crepidiodes, Crassocephalum biafiae, Vernonia amygdalina, Solanum africana, Solanium nigrum, Celosia argentea, Amaranthus hybridus* V1, *Amaranthus hybridus* V2, *Gnetum buchholsianum, Piper guineense, Xanthosoma sagittifolium, Telfairia occidentiais, Corchorus olithorus, Hibiscus esculentus* and *Basella* *rubra*. All samples were harvested in fresh conditions on the Campus of The Federal University of Technology, Akure. It is located in the humid tropical rainforest zone where the rains, which fall between the months of March and September/October, average between 1150 and 2000 mm annually. Ultisols are the predominant soil types with pH ranging between 5·0 and 6·0. All samples analysed were harvested in early August. Sampling in all cases was restricted to maturing leaves (i.e. between those not fully extended and the mature leaves below the shoot). Most of the stalks were removed and the leaves rinsed with distilled water before division into two portions. One portion was blended fresh using a Moulinex blender while the other was sun-dried and subsequently milled into powder with a laboratory hammer mill fitted with a 1 mm sieve before analysis.

Determination of proximate and mineral composition

The proximate composition was determined by the method of the Association of Official Analytical Chemists (AOAC, 1980). For the minerals, sodium and potassium were determined by flame photometry while phosphorus was determined by the vanadomolybdate method (1980). Other minerals were determined after wet digestion with a mixture of nitric acid, sulphuric acid and perchloric acids using atomic absorption spectrophotometry (AAS; SP 9 Model).

Determination of phytin and oxalate

The extraction and precipitation of phytin in the fresh and air-dried samples were done by the method of Wheeler and Ferrel (1971) while iron in the precipitate was determined as described by Makower (1970). Using a 4:6 Fe/P ratio to calculate phytin phosphorus, the phytin was determined by multiplying the phytin phosphorus by 3·55 as suggested by Young and Greaves (1940). Oxalate content was determined by the titrimetric method of Moir (1953) as modified by Ranjhan and Krishna (1980). Where extracts were intensely coloured, they were decolourised with activated charcoal (Balogun & Fetuga, 1980). Gross energy of the dried sample was determined against thermochemical grade benzoic acid standard using a Gallenkamp ballistic bomb calorimeter (Model CBB-330-0104).

RESULTS

Tables 1 and 2 show the proximate chemical composition and energy values of the dried and fresh vegetables, respectively. On average, the dried vegetables contained 19·3 g/100g crude protein (CP), 15·3 g/100 g crude fibre (CF), 12·7 g/100 g ether extract (EE), 17·4 g/100 g ash and 89·9 g/100 g dry matter (DM) while the fresh samples contained, on average, 4·2, 3·2, 0·6, 7·3 and 17·6 g/100 g CP, CF, EE, ash and DM, respectively. Higher variations in these parameters were observed in the fresh samples than in the dried ones as judged by the higher coefficients of variation (CV) in the former. The gross energy (GE) values of the dried vegetables ranged from 2192 kcal/kg in *Amaranthus hybridus* to 3732 kcal/kg in *Manihot esculenta* with a mean of 2787 kcal/kg. The energy values had a CV of 15·4%. The respective mean values for potassium, sodium, calcium and phosphorus in the fresh vegetables (Tables 3 and 4) were 4·5, 6·0, 0·9 and 0·9 g/100 g,

Table 1. Proximate composition (g/100 g) and gross energy of some air-dried leafy vegetables (means, $n = 2$)[a]

Vegetable	Family	DM	CP	EE	CF	Ash	NFE	GE
				(g/100 g)				(kcal/kg)
M. esculenta	Euphorbiacea	88·4	22·7	3·3	18·8	8·3	35·3	3722
T. triangulare	Portulaceae	82·2	16·0	31·3	11·5	19·4	4·0	2738
C. crepidiodes	Compositae	94·6	19·3	12·8	27·0	20·2	15·2	2546
C. biafrae	Compositae	87·3	13·2	13·0	12·9	15·0	33·2	2590
V. amygdalina	Compositae	89·3	21·5	5·9	11·5	15·5	34·4	2939
S. africana	Solanaceae	89·7	17·2	6·5	14·7	16·8	34·6	2930
S. nigrum	Solanaceae	87·9	21·9	13·8	6·9	17·4	28·0	2745
C. argentea	Amaranthaceae	93·5	26·7	17·5	9·2	26·8	13·2	2456
A. hybridus V1	Amaranthaceae	90·7	26·4	1·7	9·5	24·1	28·9	2415
A. hybridus V2	Amaranthaceae	90·0	17·7	1·1	10·4	23·1	37·8	2192
G. buchholsianum	Gnetaceae	93·6	13·8	23·9	29·5	4·1	22·2	3450
P. guineense	Piperaceae	92·2	19·4	10·6	18·4	18·4	20·4	2798
X. sagittifolium	Araceae	94·1	19·7	6·9	16·7	16·6	34·1	3184
T. occidentalis	Cucurbitaceae	89·1	26·8	7·5	13·2	11·2	30·4	3205
C. olithorus	Tiliaceae	87·9	13·9	2·5	10·9	14·7	45·6	2663
H. esculentus	Malvaceae	88·9	13·6	18·8	17·1	20·2	30·4	ND[b]
B. rubra	Basellaceae	89·7	17·5	2·9	21·1	24·7	23·4	ND
X		89·9	19·3	12·7	15·3	17·4	25·3	2787
SD		3·0	4·6	11·1	6·2	5·9	12·8	428
CV(%)		3·4	23·7	87·6	40·9	33·8	50·6	15·4

[a] DM, dry matter; CP, crude protein; EE, ether extract; CF, crude fibre; NFE, nitrogen-free extract; GE, gross energy.
[b] ND, not determined.

Table 2. Proximate composition (g/100 g) of some fresh leafy vegetables (means, $n = 2$)[a]

Vegetable	Family	DM	CP	EE	CF	Ash	NFE
		(g/100 g)					
M. esculenta	Euphorbiacea	25·8	6·3	1·0	5·7	6·9	5·8
T. triangulare	Portulaceae	9·1	2·5	0·4	1·7	2·5	2·1
C. crepidiodes	Compositae	16·8	3·4	0·5	1·6	11·4	1·0
C. biafrae	Compositae	15·8	2·3	0·5	1·6	9·6	1·7
V. amygdalina	Compositae	17·2	4·1	0·1	2·9	5·8	4·3
S. africana	Solanaceae	14·0	3·4	0·1	1·5	8·6	0·5
S. nigrum	Solanaceae	12·5	2·9	0·2	1·9	6·7	0·7
C. argentea	Amaranthaceae	21·2	5·8	0·4	4·5	8·3	2·2
A. hybridus V1	Amaranthaceae	18·7	5·9	0·5	1·6	10·6	0·3
A. hybridus V2	Amaranthaceae	17·1	2·9	0·2	1·7	12·3	0·1
G. buchholsianum	Gnetaceae	33·8	5·7	0·7	10·8	3·8	12·8
P. guineense	Piperaceae	20·4	2·6	2·8	2·9	11·0	1·18
X. sagittifolium	Araceae	14·7	3·7	0·7	3·2	7·2	1·0
T. occidentalis	Cucurbitaceae	13·4	4·3	0·8	2·3	6·1	0·1
C. olithorus	Tiliaceae	26·5	3·8	0·7	5·2	7·2	9·6
H. esculentus	Malvaceae	13·7	4·5	0·5	2·3	2·9	3·5
B. rubra	Basellaceae	11·1	6·9	0·2	1·6	2·4	0·1
X		17·6	4·2	0·6	3·2	7·3	2·8
SD		6·4	1·5	0·6	2·4	3·1	3·6
CV(%)		36·2	38·9	99·3	74·8	43·0	131·8

[a] DM, dry matter; CP, crude protein; EE, ether extract; CF, crude fibre; NFE, nitrogen-free extract.

Copper was the least abundant mineral in both the dry and fresh vegetables.

The phytin, phytin-P, phytin-P as % of total phosphorus and the oxalate content of both the dry and fresh vegetables are in Table 5. Generally, the concentrations of these components were higher in the dried samples than in the fresh ones. Phytin level in the dried samples ranged from 160 mg/100 g in *S. nigrum* to 660 mg/100 g in *A. hybridus* with a mean of 310 mg/100 g. In the fresh samples, it ranged from 60 mg/100 g in *G. buchholsianum* to 190 mg/100 g in *T. triangulare* with a mean of 110 mg/100 g and a CV of 27·3%. Only trace amounts of oxalate were detected in most of the fresh vegetables.

DISCUSSION

An immediate and perhaps not surprising observation from these analytical results is the higher concentration of the nutrients and anti-nutrients in the dried vegetables than in the fresh. The variation can largely be

Table 3. Mineral composition of air-dried leafy vegetables (means, $n = 2$)

Vegetable	Ca	P	K	Na	Mg	Fe	Mn	Cu	Zn
	(g/100 g)					(ppm)			
M. esculenta	0·9	0·7	5·9	8·1	0·7	425	263	50	551
T. triangulare	0·8	0·9	2·6	3·7	0·6	385	133	21	890
C. crepidiodes	0·9	0·4	3·6	4·9	1·1	349	255	20	293
C. biafrae	2·8	1·8	4·0	3·0	1·6	728	372	27	242
V. amygdalina	3·3	1·3	2·9	3·7	1·0	468	449	26	581
S. africana	3·6	1·0	5·4	2·4	1·4	372	135	51	525
S. nigrum	2·0	1·1	2·0	3·0	0·6	572	386	25	522
C. argentea	2·6	1·2	3·9	5·2	1·4	541	90	21	2229
A. hybridus V1	2·1	2·9	5·2	7·4	2·6	965	155	44	943
A. hybridus V2	1·9	0·9	4·4	6·2	2·4	1217	186	19	845
G. buchholsianum	0·6	0·5	0·6	1·5	0·3	195	144	10·3	1132
P. guineense	2·2	1·7	5·8	1·4	1·6	794	235	72	1552
X. sagittifolium	3·4	1·7	6·1	2·3	0·6	640	162	16	793
T. occidentalis	1·7	1·5	2·5	3·4	1·1	881	170	24	1525
C. olithorus	2·7	1·0	0·8	1·3	1·4	270	372	24	676
H. esculentus	8·6	1·2	1·5	2·0	0·6	383	344	9	117
B. rubra	2·3	0·7	5·8	5·1	0·6	393	58	13	405
X	2·49	1·41	3·7	3·8	1·2	564	230	28	701
SD	1·8	0·6	1·8	2·1	0·6	274	117	17	415
CV(%)	73·6	49·2	49·6	54·3	55·1	49	51	61	59

Table 4. Mineral composition of some fresh leafy vegetables (means, *n* = 2)

Vegetable	Ca	P	K	Na	Mg	Fe	Mn	Cu	Zn
	(g/100 g)					(ppm)			
M. esculenta	0·8	0·9	1·1	1·7	0·6	278	208	39	247
T. triangulare	0·1	0·7	0·4	0·7	0·2	63	15	5	138
C. crepidiodes	0·9	0·9	3·7	5·5	0·3	437	93	34	1220
C. biafrae	1·8	0·7	2·8	4·1	0·6	640	180	52	886
V. amygdalina	0·8	0·7	1·3	2·5	0·4	465	76	23	797
S. africana	1·1	0·8	2·5	2·6	1·4	579	157	29	1033
S. nigrum	2·4	0·9	1·6	1·1	0·6	609	91	64	1091
C. argentea	1·4	1·2	2·0	3·0	0·5	569	61	37	691
A. hybridus V1	1·1	1·0	3·2	3·8	1·2	606	82	39	1905
A. hybridus V2	0·8	1·9	3·2	5·1	1·2	901	86	41	545
G. buchholsianum	0·2	0·1	0·2	0·3	0·1	150	56	4	278
P. guineense	0·9	1·2	2·6	5·3	0·7	476	79	48	873
X. sagittifolium	1·1	1·3	2·2	4·3	0·3	348	165	48	674
T. occidentalis	0·6	1·4	0·6	2·9	0·4	941	135	29	341
C. olithorus	0·9	1·0	1·8	2·9	0·4	472	64	14	512
H. esculentus	0·9	0·1	0·3	0·6	0·1	88	221	ND[a]	84
B. rubra	0·3	0·2	0·6	1·6	0·1	62	21	ND	26
X	0·9	0·8	4·4	6·0	0·5	440	94	30	66
SD	0·5	0·5	2·4	3·7	0·4	262	57	19	485
CV(%)	56·8	54·6	54·6	61·9	76·0	59	61	65	725

[a]ND, not determined.

ascribed to the lower moisture content of the former. In the main, several of the dried vegetables including *M. esculenta*, *C. argenta*, *A. hybridus* and *T. occidentalis* had a CP content (on a DM basis) and energy values comparable to a number of tropical legumes including lima bean and cowpeas. The high CP content of the dry vegetables is of particular nutritional interest since, according to Schmidt (1971), about 75% of the total nitrogen in most vegetables is protein-nitrogen although this proportion varies with vegetable species. Subject to a high level of intake and amino acid supplementation, it appears feasible to meet a substantial proportion of an animal's protein and energy requirements by feeding some of these vegetables. The major drawbacks to the use of vegetable materials as major sources of nutrients by monogastrics (including man) are their high fibre and bulkiness which call for large quantities to be consumed to provide adequate levels of

Table 5. Phytic acid, phytin-P and oxalic acid content of tropical leafy vegetables (means, *n* = 2)

Vegetable	Phytic acid (mg/100 g)		Phytin-phosphorus (mg/100 g)		Phytin-phosphorus as % of total P		Oxalate (mg/100 g)	
	Dried	Fresh	Dried	Fresh	Dried	Fresh	Dried	Fresh
M. esculenta	250	100	70	30	10·0	2·9	80	20
T. triangulare	250	190	70	60	7·8	8·1	110	20
C. crepidiodes	250	160	70	40	16·3	4·7	50	10
C. biafrae	270	140	80	40	4·2	5·7	100	20
V. amygdalina	190	120	60	30	4·3	5·2	390	ND[a]
S. africana	180	120	50	30	4·7	4·2	50	ND
S. nigrum	160	100	400	30	4·1	3·1	70	ND
C. argentea	540	120	150	30	12·9	2·5	70	20
A. hybridus V1	660	140	190	40	6·5	3·7	660	40
A. hybridus V2	500	130	140	70	15·5	3·4	500	50
G. buchholsianum	310	60	90	20	16·1	15·0	50	ND
P. guineense	390	120	110	30	6·3	2·6	270	ND
X. sagittifolium	170	80	50	20	2·8	1·7	180	20
T. occidentalis	210	80	60	20	4·1	1·6	470	40
C. olithorus	230	120	70	30	6·8	3·2	170	ND
H. esculentus	190	80	60	20	4·7	32·4	790	10
B. rubra	490	80	140	20	19·6	14·4	56	50
X	310	110	90	30	8·6	6·7	270	20
SD	150	30	40	10	5·4	7·7	240	10
CV(%)	39·4	27·3	48·3	23·3	62·3	114·4	89	50

[a]ND, none detected.

nutrients. According to Oyenuga and Fetuga (1975) and Johns (1987) the presence of high fibre levels in diets can cause intestinal irritation, lower digestibility and overall decreased nutrient utilisation. Although technologies exist for extracting leaf proteins, they are still largely beyond the reach of several developing countries.

The potassium, sodium, calcium, phosphorus and magnesium contents in these vegetables were particularly high when compared with most other foods, while iron which is commonly deficient in many diets, is fairly abundant in these vegetables, particularly *Amaranthus*, *Telfaria* and *Piper* species. The high proportions of mineral elements in these vegetables when compared with other foods, such as legumes and tubers, confirm their importance as rich sources of minerals. However, there is a need for judicious selection of vegetables, especially in sodium- and potassium-restricted diets. This is important since high dietary sodium is implicated in cardiovascular and renal disorders. Similarly, high dietary sodium is discouraged in subjects who suffer from, or are prone to, hypertension.

Results in Table 5 suggest fairly high levels of phytic acid and low levels of oxalates in the vegetables. The presence of phytic acid in all the vegetables agrees with an earlier report (Lolas & Markakis, 1975) of a widespread occurrence of phytic acid in plants. Several studies including Rackis (1974), Reddy *et al.* (1982), Forbes and Erdman (1983) and Aletor (1990) have implicated dietary phytic and oxalic acids in the impairment of the efficient utilisation especially of divalent minerals such as calcium and magnesium and the subsequent development of rickets when certain legumes and cereals are fed. Dietary phytin is of particular importance in monogastric animals (including man) who lack phytase which breaks down phytin to release phosphorus for metabolism. Phosphorus utilization has become an important current issue on the question of environmental pollution. This arises from the poor digestibility of phosphorus, especially, in foods of vegetable origin (Huisman, 1991) where a high proportion of the phosphorus may be present as the poorly digested phytin-phosphorus in monogastric animals.

In view of the present study, it would appear that when dried, a number of these vegetables could be utilised as supplementary sources of protein, energy and minerals for man and/or livestock. In such circumstances, the feeding of high phytin and/or oxalate species may require dietary supplementation of the divalent minerals. The addition of the enzyme, *phytase*, to foods high in phytin has been advocated (Simons & Versteegh, 1990) as a way of enhancing P digestibility and hence utilisation.

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