Nutritional, functional property and bioactive components of the leaf products from edible vegetables

Propiedad nutritiva y funcional y componentes bioactivos de los productos de la hoja de vegetales comestibles

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ABSTRACT

Leaf meal, protein and residues were produced from fresh leaves of *Amaranthus spinosus, Amaranthus viridis, Telfairia occidentalis, Vernonia amygdalina, Bidens pilosa, Cnidoscolus aconitifolius, Manihot spp and Basella alba* L and characterized for their proximate composition and some bio-active components. The leaf protein concentrate (LPC) in addition were characterized for their functional properties while three LPC with the highest crude protein (CP) content were analyzed for their amino acid profile and compared with FAO recommended pattern. Leaf meals (LM) contained on the average 16.25% ash (8.47–23.97%; CV%: 32.30), 24.96% crude protein (11.85 – 33.87%; CV%: 30.40), 9.94% crude fat (CF) (6.34 – 17.41%; CV%: 33.95) and 12.22% crude fibre (CFi) (5.73–18.45%; CV%: 32.33). In LPC products, the CP increased by 17.49-41.98%, CF by 11.82-35.73% while Cfi decreased by 24.38 – 83.71%. About 45 g of LPC from *Manihot* spp, 69g from *T. occidentalis* and 52 g of *C. aconitifolius* could be consumed to meet the 26g/d plant protein recommended by FAO. The LPC was limiting in methionine (1.41 - 1.62g16 g^{-1}N; CV% of 6.94) and cystine (0.79 - 1.26 g 16 g^{-1}N, CV% of 23.48) suggesting that any dietary formulation involving these LPC would need supplemental methionine. Water absorption capacity ranged from 200.02-390.03% while the oil absorption capacity varied: 60.74- 117.50%. The foaming capacity, foaming stability, emulsion capacity, emulsion stability and least gelation concentration averaged 6.31, 2.24 45.02, 51.73 and 5.84%, respectively. Fractionation could enhance the nutritive potentials of these vegetables and make them serve as possible protein food alternatives for well known plant proteins in regions where proteins are in short supply.

Key words: Nutritional property, functional property, bioactive compounds, leafy vegetables

RESUMEN

Se produjeron harina de hojas, proteínas y residuos a partir de hojas frescas de *Amaranthus spinosus, Amaranthus viridis, Telfairia occidentalis, Vernonia amygdalina, Bidens pilosa, Cnidoscolus aconitifolius, Manihot* spp y *Basella alba* L y se caracterizó por su composición proximal y algunos componentes bio-activos. El concentrado de proteína de hojas (CPH) además se caracterizó a través de sus propiedades funcionales, mientras que los tres CPH con el mayor contenido de proteína cruda (PC) se analizaron para determinar el perfil de aminoácidos y se compararon con el patrón recomendado de la FAO. Los alimentos de las hojas (AH) tuvieron en promedio 16,25% de cenizas (8,47 a 23,97%, CV%: 32,30), 24,96% de PC (11,85 a 33,87%, CV%: 30,40), 9,94% de grasa cruda (GC) (6,34 - 17,41%, CV%: 33,95) y 12,22% de fibra cruda (FC) (5,73 a 18,45%, CV%: 32,33). En los productos del CPH, la PC aumentó en un 17,49 a 41,98%, GC por 11,82 a 35.73%, mientras que la FC disminuyó en un 24,38 a 83,71%. Aproximadamente 45 g de CPH de *Manihot* spp, 69 g de *T. occidentalis* y 52 g de *C. aconitifolius* podrían ser consumidos para satisfacer la proteína vegetal de 26g /d recomendada por la FAO. EL CPH fue limitante en metionina (1,41 a 1,62 g 16g^{-1}N, CV% de 6,94) y cistina (0,79 a 1,26 g 16 g^{-1} N, CV% de 23,48) lo que sugiere que cualquier formulación de la dieta que incluyan éstos CPH necesitarían suplementos de metionina. La capacidad de absorción de agua varió de 200,02 hasta 390,03%, mientras que la capacidad de absorción de aceite varió de 60,74 a 117,50%. La capacidad de formación de espuma, la estabilidad de la formación de espuma, la capacidad emulsionante, la estabilidad de la emulsión y la menor concentración de gelificación promediaron 6,31; 2,24; 45,02; 51,73 y 5,84%, respectivamente. El fraccionamiento pudiera mejorar el potencial nutritivo de estos vegetales y ponerlos al servicio como posibles alternativas de alimentos proteicos para las proteínas vegetales bien conocidas en las regiones donde las proteínas son escasas.

Palabras clave: Propiedad nutricional, propiedad funcional, compuestos bioactivos, hortalizas de hoja

INTRODUCTION

The need to add value to the existing food items such as the common edible vegetables so as to increase their nutritional potential has long been neglected in Nigeria. In most developed nations of the world, most of the green vegetables are either canned or refrigerated to increase their shelf life and nutritional potentials. In more advanced nations some are fractionated to leaf protein concentrates and are used as condiments in the foods of aged, pre-school children and some protein vulnerable groups (Eggum, 1970; Barbeau, 1989). However, green vegetables have long been recognized (Byers, 1961, Oke, 1968; Aletor *et al*., 2002) as the cheapest and most abundant potential sources of protein because of their ability to synthesize amino acids from a wide range of virtually unlimited and readily available primary materials such as, water, CO_2 and atmospheric nitrogen in sunlight. Although, leafy vegetables are good sources of protein their use by man and non-ruminants is limited because of their high cellulose content and, in some cases, the presence of inherent toxic factors. However, if the cellulose content was separated mechanically, cellulose-free protein from vegetables could supply as much as 10 – 20g protein/person/day (Oke, 1973).

In addition, the cellulose-free protein could be stored dry and use as condiment. Available literature (Eggum, 1970; Barbeau, 1989; Agbede and Aletor, 2003 & 2004; Agbede *et al*., 2007) clearly stated that, apart from lower methionine and cystine content, the amino acid profiles of the leaf protein from most species compare favourably and surpass those of FAO/WHO (1973) and whole egg amino acid pattern. The leaf protein concentrate as a way of adding value to the leafy vegetables is still under-studied and consequently under-utilized in Nigeria unlike in Europe, America and Asia.

The need to add value to the leafy vegetables through fractionation method is now more compelling in the face of the present global climate change, which is presently affecting the planting time of these vegetables in sub-Sahara Africa. Incidentally this region has the highest percentage of resource poor persons who need cheap sources of high quality protein in which leaf protein concentrates could serve as good sources.

Therefore the main objectives of this study are to add value by a way of producing and characterizing the leaf products from *Amaranthus spinosus* (Spiny amaranth), *maranthusviridis* (Slender amaranth), *Telfairia occidentalis* (Fluted pumpkins), *Vernonia amygdalina* (Bitter leaf), *Bidens pilosa* (Black jack), *Cnidoscolus aconitifolius* (Johnston leaf), *Manihot* spp. (Cassava foliage) and *Basella alba* L. (Indian spinach), which are common edible vegetables in Nigeria with respect to their proximate composition, amino acid profile and some anti-nutrients. Also studied are certain functional attributes of the leaf protein concentrates from these leafy vegetables.

MATERIALS AND METHODS

Vegetable materials

Amaranthus spinosus, A. viridis, Telfairia occidentalis, Vernonia amygdalina, Bidens pilosa, Cnidoscolus aconitifolius, and *Basella alba* L. were purchased from Akure main market in fresh conditions while *Manihot spp* foliage leaves were obtained fresh from the Teaching and Research farm, Federal University of Technology, Akure, Nigeria. All the leaves were harvested during the early hours in June (rainy season).

Leaf meal production

Freshly collected vegetable leaves were brought to the laboratory. The plucked leaves were put in a tray and sun-dried for 4 – 5 days. The dried leaves were then milled using laboratory hammer mill (Dietz, Dettingen-Teck, Germany) and stored in a deep freezer prior to analysis.

Leaf protein concentrate production

Leaves from individual vegetable species were plucked, weighed and washed prior to pulping as described by Fellows (1987). The pulping ruptured the plant cell walls. The juice, which contains most of the plant proteins, was squeezed from the leaf residue by using a press. The separated leaf juice was heated in batches to 80 - 90°C for 10 min. this procedure coagulated the leaf proteins from the whey. The protein coagulum was separated from the whey using a rubber hose to siphon the hot wheys as described by Agbede and Aletor (2004). The coagulated proteins were then filtered through muslin cloth and pressed with a screw-press to remove the remaining whey. The leaf protein was then washed with water, re-pressed and sun-dried.

Leaf residue production

Leaf residue is the remaining fibrous fraction after pulping. This was spread in trays and sun-dried. The samples were milled to fine powder using a laboratory hammer mill (Dietz, Dettingen-Teck, Germany), sieved and packed in labeled air-tight containers and deep frozen at -18^{o}C until analysed.

Chemical analysis

Proximate compositions of the samples were determined in triplicate for moisture, fat, ash, and crude fibre, using methods described by AOAC (1995). The amount of nitrogen was determined by the micro-Kjeldahl method and the percentage of nitrogen was converted to crude protein by multiplying by 6.25. The nitrogen-free extract was determined by difference.

Determination of the functional properties of the LPC

The water absorption capacity (WAC) and fat emulsion stability were determined by the procedure of Beuchat (1977). The fat absorption capacity (FAC) was determined as described by Sosuslki (1962). Similarly, the lowest gelation concentration (GLC), foaming capacity (FC) and foaming stability of the LPCs were determined using the technique of Coffman and Garcia (1977).

Determination of anti-nutrients

Tannin acid determination

Finely milled samples (200mg in 10mL of 70% aqueous acetone) were extracted for 2 hrs at 30ºC in a water-bath using a Gallenkamp orbital shaker (Electro Ltd, Avon, UK) at 120 rpm. Pigments and fat were removed from the samples by extracting with diethyl ether containing 1% acetic acid. Total polyphenols (as tannic equivalent) were determined as described by Makkar and Goodchild (1996).

Phytin acid determination

Eight g of each sample was soaked in 200 mL of 2% hydrochloric acid and allowed to stand for 3 h. The extract was thereafter filtered through two layers of hardened filter paper. Filtrate of 50 mL was pipetted in triplicate into 400 mL capacity beakers before the addition of 10 mL 0.3% ammonium thiocyanate solution as an indicator, and 107 mL of distilled water to obtain the proper acidity (pH4.5). The solution was then titrated with a standard iron chloride ($FeCl_3$) solution containing 0.00195 g Fe mL-^{1} until a brownish yellow colour persisted for 5 min. Phytin-phosphorus was determined and phytin content was calculated by multiplying the value of phytin-phosphorus by 3.55 (Young and Greaves,1940). Each milligram of iron is equivalent to 1.19 mg of phytin-phosphorus.

Oxalic acid determination

The method of Day and Underwood (1986) was used. One g of sample was ground in water and 75 ml of 1.5M H_2SO_4 was added. This solution was stirred intermittently for about 1 h and filtered using Whatman No 1 filter paper; 25ml of the filtrate was collected and titrated hot (80 - 90 ^{o}C) against 0.1ml KMnO4 solution to the point when a faint pink colour appeared. The oxalate content of the test samples were then estimated using the relationship:

$$\text{mg/g Oxalate } \frac{\text{Titre value x } 0.9004}{\text{Wight of sample}}$$

Amino acid analysis

The LPC (50-75 mg) were hydrolysed by refluxing for 24 h in a heating block previously heated to 110±1ºC. The hydrolysate was cooled and quantitatively transferred to a 50 mL flask and diluted to volume with water. After filtration, a10mL aliquot of the filtrate was heated in a rotary evaporator (40EC) to remove excess acid before analysis using high-performance liquid chromatography (HPLC) (Varian Inc., Palo Alto, CA, USA) and a Shimadzu RF-535 Florescence detector (GL Sciences Inc., Tokyo, Japan) set at an excitation wavelength of 325 nm and an emission wavelength of 465 nm. Separation was achieved in an adsorbosphere OPA-HR (150 * 4.6 mm) column (Alltech, Carnforth, UK). The mobile phase was 1, 4-dioxan and 2-propanol (HPLC grade). Methionine was determined as methionine sulphone and cysteine as cysteic acid after performic acid oxidation. To correct for slight fluctuations in amino acid peaks, DL-amino-n-butyric acid was used as an internal standard.

RESULTS AND DISCUSSION

Table 1 showed that the crude protein content of the unprocessed leaf meals varied from 11.85 %

DM in *B. pilosa* leaf meal to 33.87% DM in *C. aconitifolius* leaf meal with a coefficient of variation of 30.40%. The crude fat varied from 9.60 % DM in *A. viridis* to18.51 % DM in *C. aconitifolius* with a CV value of 33.95. The crude fat content of the leaf meal averaged 12.22 % DM while the ash and carbohydrate contents averaged 16.25 (range: 8.47 – 23.97% DM) and 36.62 (range: 29.64– 44.36 % DM), respectively. These findings suggest that the consumption of these leafy meals could lead to uptake of some essential nutrient components such as protein and fat. The high crude protein values of *T. occidentalis, V. amygdalina, C. aconitifolius, Manihot spp* and *B. alba* is worthy of noting. The protein contents of *A. spinosus, A. viridis, T. occidentalis, V. amygdalina, B. pilosa* and *B. alba* were consistently lower than the values reported for some leaf vegetables. However, the protein values for *C. aconitifolius* and *Manihot spp* compared well with the value reported by Aletor *et al* (2002) and even higher than those reported for some tropical leguminous plants (Agbede, 2006). In general, the crude protein (CP) of these leafy vegetables compared favourably with, and in some cases surpassed, those reported for most legumes grown in West Africa (FAO, 1972, Igene *et al*., 2001 and Oke *et al*., 1995).

The leaf protein concentrates which are products of fractionation processes led to enhanced crude protein, crude fat and decrease in crude fibre (Table 2). For instance, the crude protein increased by between 17.49% in *A. spinosus* and 41.98 % in *Manihot* spp. with a mean increase of 31.26% in the LPC. Also, the increment in crude fat varies from 11.82% in *A. spinosus* to 35.73% in *T. occidentalis* with a mean increment of 22.30%. However, fractionation led to a decrease in the crude fibre by 24.38 - 83.71%.This study confirmed that value can be added to these leafy vegetables under study through their fractionation to LPC with attendant improvement in their protein, energy (fat) and fibre contents. Subject to a high intake of LPC from these leafy vegetables, it is conceivable that quite a large proportion of plant protein requirement could be met among the resources poor population. Of all the LPCs, those from *A. spinosus, A. viridis, T. occidentalis, C. aconitifolius, Manihot* spp. and *B. alba* with CP values of 35.39, 30.79, 37.47, 49.11, 57.77 and 31.71% DM, respectively appear to be the only ones which could be recommended for inclusion in human diets and non-ruminant diets in general as possible protein and calorie supplements especially where better known conventional plant protein are in

Table 1. Proximate composition (% dry matter) of leaf meals (n = 3) in Akure, Nigeria.

Vegetables	Ash	Crude protein	Crude fat	Crude fibre	Carbohydrate
Amaranthus spinosus	18.28	29.22	10.59	10.71	31.20
Amaranthus viridis	8.47	19.12	9.60	18.45	44.36
Telfairia occidentalis	12.76	26.67	17.41	13.52	29.64
Vernonia amygdalina	18.17	20.14	7.14	16.71	37.84
Bidens pilosa	20.53	11.85	9.35	5.73	52.54
Cnidoscolus aconitifolius	14.58	33.87	10.51	9.63	31.41
Manihot spp. foliage	13.28	33.52	6.34	13.81	33.05
Basella alba	23.97	25.28	8.57	9.23	32.95
Mean	16.25	24.96	9.94	12.22	36.62
CV%	32.30	30.40	33.95	32.33	21.80

Table 2. Proximate composition (% dry matter) of leaf protein concentrates (n = 3) in Akure, Nigeria.

Vegetables	Ash	Crude protein	Crude fat	Crude fibre	Carbohydrate
Amaranthus spinosus	20. 78	35.39	12.01	3.34	28.48
Amaranthus viridis	11.18	30.79	11.21	10.21	36.61
Telfairia occidentalis	18.87	37.47	20.98	8.76	13.92
Vernonia amygdalina	11.92	29.24	11.11	10.38	37.35
Bidens pilosa	14.51	20.23	11.83	3.68	49.75
Cnidoscolus aconitifolius	8.01	49.11	12.29	2.77	27.82
Manihot spp. foliage	3.16	57.77	9.47	2.25	27.35
Basella alba	12.07	31.71	12.42	6.98	36.82
Mean	11.34	36.46	12.67	6.05	32.26
CV%	43.26	32.56	27.55	56.75	32.42

short supply. FAO recommended that 65g/day/person of protein should be consumed out of which about 60% must come from animal protein origin. This represents 39 g/day animal protein leaving 26g/day to be consumed from plant protein. From this present study, about 45 g of LPC from *Manihot* spp., 69 g from *T. occidentalis* LPC and 52 g of *C. aconitifolius* could be consumed to meet the 26g protein. Thus, suggesting the adequacy of these LPC as possible protein food alternatives for well known plant proteins.

However, crude protein and fat contents of some of the LPC were in some cases comparable to those reported for the LPC from several tropical leafy vegetables (31.7 - 34.6 %DM) (Oke, 1973 and Aletor *et al.*, 2002), and even surpassed those reported elsewhere by Agbede (2006) for some under-utilized tropical browse plants (20.1 - 43.0%DM). Table 3 shows that leaf residues from the LPC fractionation varies from 18.03% DM in *Manihot* spp. foliage to 22.94% DM in *C. aconitifolius*. However, the incorporation of these fibrous residues in non-ruminant diets could be beneficial. This is because fibre which, is the undigested part of food can help to promote health fitness; by preventing several diseases from spreading. Thus, the fibrous component (Table 3) though low in protein are rich sources of cellulose, which when consumed will not only provide energy but the undigested portion could be of health benefit to their consumers.

The amino acid (AA) profiles of the three LPCs with the highest crude protein were analyzed and presented in Table 4. The LPCs had varied amino acid profiles as shown by the values of the CV. Of the entire AA measured, 13 out of 17 were higher in *Manihot* spp. LPC than those of the *C. aconitifolius* and *T. occidentalis*. However, all the LPCs were limiting in the sulphur-containing amino acids: methionine (range: 1.41 - 1.62g16g^{-1} N; CV% of 6.94) and cystine (range: 0.79 - 1.26 g16 g^{-1}N, CV% of 23.48) suggesting that any dietary formulation involving these LPC would either need supplemental methionine or the LPC should be fed in combination with ingredients high in these amino acids for complementarily. Of interest is the balance of lysine, leucine, isoleusine, valine and threonine when compared with the amino acid balance proposed by FAO/WHO (1973) and whole egg amino acids profile (Robinson, 1987).

Table 5 shows the mean values of WAC, OAC, FC, FS, EC, ES and LGC of the different vegetable leaf protein concentrates. Water absorption capacity ranged from 200.02% in *C. aconitifolius* to 390.03% in *B. alba* while the OAC varied from 60.74 *A. viridis* to 117.50% in *V. amygdalina*. Also, the FC varied from 1.02% in *Manihot* spp. foliage to 12.12% in V. amygdalina and the FS averaged 2.24% (range: 1.02 – 4.01%). The EC, ES and LGC averaged 45.02 (CV%: 19.60), 51.73 (CV%: 6.32) and 5.84 % (CV: 61.07), respectively. This suggests that these leaf protein concentrates have high potential for the development of different food products. The values for WAC reported here compared favourably with the ones reported for some seeds by Oshodi and Ekperingin (1989). Water absorption capacity values ranging from 149.1 to 471.5% are considered critical in viscous foods, such as soups and gravies. Except for *A. spinosus* and *A. viridis*, the values reported here compared and in some cases surpassed the value reported by Oshodi and Ekperingin (1989) for pigeon pea flour. However, all the LPCs had higher values than those reported by Aletor *et al.* (2002). This suggests that these LPCs may be good flavour

Table 3. Proximate composition (% dry matter) of vegetable leaf residues from leaf protein extraction (n = 3) in Akure, Nigeria.

Vegetables	Ash	Crude protein	Crude fat	Crude fibre	Carbohydrate
Amaranthus spinosus	16.83	7.58	6.61	18.74	50.24
Amaranthus viridis	17.87	4.45	5.32	20.91	51.45
Telfairia occidentalis	8.56	4.84	6.99	21.46	58.15
Vernonia amygdalina	8.81	3.69	4.82	20.55	62.13
Bidens pilosa	13.42	3.38	6.01	21.66	55.53
Cnidoscolus aconitifolius	9.68	6.42	6.04	22.94	54.92
Manihot spp. foliage	4.31	9.13	3.96	18.03	64.57
Basella alba	11.18	7.55	5.19	18.52	57.56
Mean	11.33	5.88	5.62	20.35	56.82
CV%	39.94	35.62	17.62	8.58	8.62

retainers. Except for the *A. viridis* and *B. pilosa* LPC, the values of EC falls within the values (47.8 – 64.8%) and the ES values were within the range reported (47.1 - 48%) by Lin *et al*. (1974) and Aletor *et al*. (2002). This clearly indicates the potentials of these LPCs as additives for the stabilization of emulsions in the production of soups and cake. The FS was between 1.02 and 4.01% at 30 min which further confirm that LPCs may not be useful as whipping agent.

Table 6 shows that the LMs, LPCs and their corresponding residues contain phytin, total phenol and oxalate, which varied with vegetable species and the leaf products. Fractionation of the leaf meal in some cases reduce or even totally inactivated the anti-nutritional components in LPC but this did not follow any specific order, suggesting that fractionation has the ability to enhance the nutritive potentials of these leafy vegetables (Oke 1973, Olatubosun *et al.*, 1972 and Agbede, 2006).

Table 4. Amino acid profile (g $16g^{-1}$ N) of the three leaf protein concentrates with the highest crude protein values (n = 2) in Akure, Nigeria.

Amino Acid	*Telfairia occidentalis* (CP = 37.47% DM)	*Manihot* spp. (CP = 57.77% DM)	*Cnidoscolus aconitifolius* (CP = 49.11% DM)	Mean Value	Coefficient of variation (%)	FAO/WHO (1973) Recommended pattern	Whole Egg *
Lysine	5.24	6.37	5.89	5.83	9.72	5.5	6.3
Histidine	2.14	2.08	2.08	2.10	1.65		2.4
Argine	5.01	4.83	5.17	5.00	3.40		6.1
Aspartic acid	8.50	9.74	8.38	8.87	8.49		
Threonine	3.37	4.25	3.92	3.85	11.56	4.0	5.1
Serine	3.04	4.99	3.53	3.85	26.33		
Glutamic acid	9.54	10.15	10.00	9.90	3.21		
Proline	3.46	3.93	3.46	3.62	7.50		
Glycine	4.90	5.09	4.80	4.93	2.99		
Alanine	4.71	5.85	5.24	5.27	10.83		
Cystine	0.79	1.19	1.26	1.08	23.48		1.8
Valine	4.28	5.2	5.26	4.91	11.18	5.0	7.6
Methionine	1.51	1.62	1.41	1.51	6.94		3.2
Isoleucine	4.00	4.88	4.50	4.46	9.90	4.0	5.6
Leucine	6.39	8.08	8.90	7.79	16.43	7.0	8.3
Tyrosine	2.86	3.94	3.18	3.33	16.68	6.0	4.0
Phenylalanine	3.60	5.38	4.28	4.42	20.32		5.1

CP = Crude protein and DM: Dry matter. * Cited by Robinson (1987)

Table 5. Functional properties (%) of leaf protein concentrate (n = 3) in Akure, Nigeria.

Vegetables	WAC	OAC	FC	FS at 80 min	EC	ES	LGC
Amaranthus spinosus	240.02	78.30	3.13	2.09	48.97	50.21	2.22
Amaranthus viridis	210.05	60.74	10.05	3.04	37.34	57.01	4.30
Telfairia occidentalis	270.11	82.37	8.11	2.59	49.46	48.09	6.11
Vernonia amygdalina	290.61	117.50	12.12	2.11	49.75	56.47	4.03
Bidens pilosa	270.05	113.64	4.02	2.03	25.91	52.03	14.02
Cnidoscolus aconitifolius	200.02	78.39	4.01	1.03	50.02	50.02	6.02
Manihot spp. foliage	220.03	105.83	1.02	1.02	49.75	50.00	6.02
Basella alba	390.03	94.09	8.03	4.01	48.97	50.04	4.02
Mean	261.37	91.36	6.31	2.24	45.02	51.73	5.84
CV%	23.37	21.71	60.65	44.42	19.60	6.32	61.07

WAC = water absorption capacity, OAC = oil absorption capacity, FC = foaming capacity, FS = foaming stability, EC = emulsion capacity, ES = emulsion stability and LGC = least gelation concentration,

Table 6. Some anti-nutrient contents (g/100g DM) of the leaf meals and their corresponding products in Akure, Nigeria.

	Leaf Meal			Leaf Protein Concentrate			Leaf Residues		
Vegetables	Tannin	Phytin	Oxalate	Tannin	Phytin	Oxalate	Tannin	Phytin	Oxalate
Amaranthus spinosus	0.13	69.21	2.21	0.15	27.20	2.12	ND	49.86	1.04
Amaranthus viridis	0.05	51.86	2.39	ND	28.03	2.97	ND	50.27	1.04
Telfairia occidentalis	0.23	16.06	2.30	0.09	15.65	4.38	0.04	24.71	1.35
Vernonia amygdalina	0.33	42.03	1.31	0.13	32.53	2.03	0.06	42.03	1.31
Bidens pilosa	1.02	108.76	2.03	ND	14.43	1.31	ND	51.10	0.81
Cnidoscolus aconitifolius	0.11	16.49	3.74	0.03	17.29	1.86	ND	24.31	1.13
Manihot spp. foliage	0.32	45.97	3.00	ND	65.11	1.60	0.19	21.41	1.13
Basella alba	0.03	60.14	2.61	ND	44.09	1.76	0.11	67.79	0.68

ND = Not detected

CONCLUSIONS

From the analytical information especially on the crude protein, fat, crude fibre, amino acids and some functional attributes of the leaf protein concentrate (LPC) from these vegetables understudy it is clear that fractionation has the potential to improve their nutritive values for human and monogastric animal consumption in regions where plant protein shortage is endemic. The LPC from these leafy vegetables may be fed as components of some low-nitrogenous foods such Gari and yam or cassava products which are the main stable foods in sub Sahara Africa.

LITERATURE CITED

Adeyeye, E. I.; A. A. Oshodi and K. O. Ipinmoriti. 1994. Functional properties of some varieties of African yam bean (*Sphenostylis sternocarpa*) flour. Intern. J. Food Sci. and Nutr. 45*:* 829-836.

Agbede, J. O. 2006. Characterisation of the leaf meals, protein concentrates and residues from some tropical leguminous plants. J. Sc. Fd. and Agric. 6: 1292-1297.

Agbede, J. O. and V.A. Aletor. 2003. Evaluation of weaning foods from G*lyricidia* and *Leucaena* leaf protein concentrates and some commercial brands in Nigeria. J. Sc. Fd. and Agric. 84: 21-30.

Agbede, J. O. and V. A. Aletor. 2004. Chemical characterization and protein quality evaluation of leaf protein concentrates from *Glyricidia sepium* and *Leucaena leucocephala*. Inter. J. Fd. Sci. and Technol. 39: 253-261.

Agbede, J. O.; M. Adegbenro, O. Aletor and A. Mohammed. 2007. Evaluation of the nutrition value of *Vernonia amygdalina* leaf protein concentrates for infant weaning foods. Acta Alimentaria 36 (3): 387-393.

Aletor, O.; A. A. Oshodi and K. Ipinmoroti. 2002. Chemical composition of common leafy vegetables and functional properties of their leaf protein concentrates. Food Chem. 78: 63-68.

AOAC. (Association of Official Analytical Chemists). 1995. Official method of analysis, 16th edn. Washington DC: Journal of the Association of Official Analytical Chemist, Chapter 4. p. 17-34.

Barbeau, W. E. 1989. Nutritional evaluation of experimental weaning foods prepared from green leaves, peanut oil and legume flour. Plant Fd. Hum. Nutr. 39: 381-395.

Beuchat, L. R. 1977. Functional and electrophoretic characteristics of succinylated peanut flour protein. J. Agric. and Food Chem. 25: 258-261.

Byers, M. 1961. Extraction of protein from the leaves of some plants growing in Ghana. J. Sci. and Food Agric. 12: 20-30.

Coffman, C. W. and V. V. Garcia. 1977. Functional properties and amino acid content of a protein isolate from mung bean flour. J. Food Tech. 12: 473-484.

Day, R. A. and A. L. Underwood. 1986. Quantitative analysis. 5th Edition, Prentice-Hall Publication, New York, United States of America, 701 p.

Eggum, B. O. 1970. Protein quality of cassava leaves. Brit. J. Nutr. 24: 761-768.

Fellows, P. 1987. Village scale leaf fractionation in Ghana. Trop. Sci. 27: 77-84.

Food and Agricultural Organization (FAO)/World Health organization (WHO). 1973. Energy and protein requirements. Technical Report Series. No 52, Geneva, Switzerland. p. 1-118.

Food and Agricultural organization (FAO). 1972. Food composition table for use in East Asia, Food and Agriculture Organisation, Rome, and U. S. Dept. of Health, Education and Welfare, Washington, D.C. United States of America.

Igene, F. U.; J. O. Agbede and J. O. Omuetti. 2001. Nutrient and anti-nutrient composition of raw and processed winged bean seeds (*Psophocarpus tetragonolobus*). J. Appl. Sci. 4: 2305-2318.

Lin, M. J. Y.; E. S. Humbert and F. W. Sosulki. 1974. Certain functional properties of sunflower meal products. J. Food Sci. 39: 368-370.

Makkar, A. O. S. and A. V. Goodchild. 1996. Quantification of tannins. A laboratory manual. p. iv + 25. Allepo, Syria: International Centre for Agricultural Research in the Dry Areas (ICARDA).

Oke, O. L. 1968. Chemical changes in some Nigerian vegetables during growth. Exp. Agric. 4: 345-349.

Oke, O. L. 1973. Leaf protein research in Nigeria. A review. Trop. Sci. 15 : 139-155.

Oshodi, A. A. and V. A. Aletor. 1993. Functional properties of hamagglutinins (lectins) extracted from three edible varieties of Lima beans (*Phaseolus lunatus*). Inter. J. Food Sci. and Nutr. 44: 133-136.

Oshodi, A. A. and M. M. Ekperingin.1989. Functional properties of pigeon pea (*Cajanus cajan*) flour. Food Chem. 34: 187-191.

Olatubosun, D. A.; B. K. Adadevoh and O. L. Oke. 1972. Leaf protein: a new protein source for the management of protein calorie malnutrition in Nigeria. Nig. Med. Jour. 2: 195-199.

Robinson, D. S. 1987. Protein sources: An important amino acids of some animal foods. Food Biochemistry and Nutrition value (1st edition), Published by Longman Scientific and Technical, United Kingdom. p 147 p.

Sosulski, F. W. 1962. The centrifuge method for determining flour absorption in hard red spring wheats. Cereals Chem. 39: 344-350.

Young, S. M. and J. S. Greaves. 1940. Influence of variety and treatment on phytin contents of wheat. Food Res.5: 103-105.