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Proximate composition, nutritionally valuable minerals and functional properties of *Adenopus breviflorus* benth seed flour and protein concentrate

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The proximate analysis of *Adenopus breviflorus* benth seeds showed that the whole seed flour, dehulled full-fat seed flour and protein concentrate had crude protein contents of 28·6, 30·2 and 76·5% while fat contents were 47·7, 54·2 and 1·4%, respectively. The ash content ranged from 3·49% in samples with hull to 2·06% for the protein concentrate. The results also showed that potassium and calcium are evenly distributed in the seed while sodium, magnesium, iron, phosphorus and manganese are more concentrated in the cotyledon. The water absorption capacity of the flours varied from 112·5% for sample without hull to 201·5% for the protein concentrate while the oil absorption capacity varied from 125·9% to 206·7% depending on the sample under consideration. The least gelation concentrations and emulsion capacity were relatively good. The foaming capacity was low but relatively stable. Protein solubility studies showed that the protein of the protein concentrate was soluble at both acidic and basic pH.

INTRODUCTION

The chemical composition and functional properties of legumes are important in their uses for new food products (Martinez, 1979; Platt, 1980; Ukhun & Ifebigh, 1988; Oshodi & Ekperigin, 1989). They are sources of protein and contribute substantially to the protein intake of a significant proportion of the world population, particularly in developing countries (Aletor, 1987; Ukhum & Ifebigh, 1988; Aletor & Aladetimi, 1989). Unfortunately, most developing countries are generally not producing enough food, including legumes (Aletor & Aladetimi, 1989). Thus, it is necessary to make maximum use of what is available. However, many of the edible legumes which could serve as sources of protein are under-utilized; these include, for example, pigeon pea, lima beans, sphenostilic sternocarpa and Lablab bean (Aletor & Aladetimi, 1989). The under-utilization of these plant protein sources may not be unconnected with traditional diets and eating habits.

Adenopus breviflorus benth is an oil seed commonly found in the savannah forest region of southern Nigeria. The seeds are used as a soup ingredient. They can be ground with hull or without hull for preparation of the soup. It is also known that, within some ethnic groups, the seeds are roasted and eaten whole. There is no information about the proximate chemical composition or the nutritionally valuable minerals and functional properties of *Adenopus breviflorus* benth flour which could be used to assess its value in the food industries other than direct consumption by farmers. Therefore, this report presents the results of investigations on *Adenopus breviflorus* benth flour.

MATERIALS AND METHODS

Adenopus breviflorus benth seeds were obtained in the dried form from the local market at Udaba-Ekperi market in Bendel State of Nigeria. The seeds were screened to remove stones and immature seeds, then the seeds were mixed thoroughly and samples for milling were taken by the quartering method from which 500 g of the whole seeds (i.e. seed with hull) were weighted from a suitable part of the quartering process and dry-milling into flour, stored in polythene bags and kept in the freezer until used. Five hundred grams of the dehulled sample was dry-milled into flour, stored in polythene bags and kept in the freezer until used. Five hundred grams of the dehulled sample was dry-milled and defatted using a Soxhlet apparatus with petroleum ether (boiling point 40–60°C) as solvent (Pearson, 1976). The defatted sample was reground and stored as above for use as protein concentrate.

Proximate analyses of the *Adenopus breviflorus* benth flours for moisture and fat were carried out in at least triplicate using the methods described by AOAC (1975). Nitrogen was determined by the micro-Kjeldahl method described by Pearson (1976) and the percentage nitrogen was converted to crude protein by multiplying by 6·25. The fibre and ash contents of the samples were determined using the method described by Pearson (1976).

The minerals were analyzed from solutions obtained by first dry-ashing as follows: 5 g of each sample was placed in a dish and heated gently on a Bunsen burner in a fume-cupboard until the charred mass was in a suitable condition, i.e. when the sample had ceased to emit smoke and it was transferred to a muffle furnace at 525°C. Heating was continued until all the carbon was burned away and the dish plus ash was transferred to a desiccator to cool. The ash obtained was dissolved in distilled de-ionized water with a few drops of concentrated hydrochloric acid in a standard flask. Sodium and potassium were determined with a flame photometer (Carning, model 45) using NaCl and KCl solutions respectively, for preparation of standards. All other metals in the report were determined by means of atomic absorption spectrophotometer (PYE Unicam SP9) using the following salts: $CaCO_3$, $MgSO_4 . 7H_2O$, $FeSO_4 . (NH_4)_2SO_4 . 6H_2O$, MnO_2, $Zn(NO_3)_2$ and $CuSO_4$ for the preparation of standards. Phosphorus was determined colorimetrically using a Spectronic 20 as described by Pearson (1976) with KH_2PO_4 as a standard.

The protein solubilities of the samples were determined at various pH values by the method described by Oshodi and Ekperigin (1989). The least gelation concentration, water and oil absorption, and foaming properties of the samples were determined by the method described by Sathe *et al.* (1982), while the emulsion capacity was determined by the method of Ige *et al.* (1984).

RESULTS AND DISCUSSION

Proximate compositions of the whole seed flour, dehulled seed flour and protein concentrate are presented in Table 1, which shows that *Adenopus breviflorus* benth is rich in crude fat (47·67% in the whole seed and 54·16% in the dehulled sample). The crude fat content of the dehulled sample is higher than those of the four oilseed samples reported by Ige *et al.* (1984), i.e. *Tetracarpidium conophorum* (50·6%), *Cucumeropis edulis* (43·7%), *Citrullus vulgaris* variety 1 (47·7%) and *Citrullus vulgaris* variety 2 (51·1%) and higher than the value obtained for *Colocynthis citrullus* L. (52·0%) (Akobundu *et al.*, 1982). The crude protein of dehulled *Adenopus breviflorus* benth is 30·2% which is high and comparable to the crude protein content of the four oilseed samples reported by Ige *et al.* (1984) and that of *Colocynthis citrullus* L. reported by Akobundu *et al.* (1982). The crude protein content of the protein concentrate is 76·5%. This high protein content may be valuable for food formulation.

Table 2 shows the mineral content of the whole seed flour (i.e. seed with hull) and the dehulled full-fat seed flour. The table indicates that potassium and calcium are evenly distributed while sodium, magnesium, iron, manganese and phosphorus are more concentrated in the cotyledon. The values obtained for magnesium, iron, manganese and phosphorus are reasonably high and may satisfy the nutritional needs of the consumers (FAO, 1968).

The results for variation of protein solubility with pH are shown in Fig. 1 which indicates that the protein is least soluble in the seed flour with hull in both the

Table 1. Proximate composition of the *Adenopus breviflorus* benth whole seed flour, dehulled full-fat seed flour, and protein concentrate

Components	Whole seed flour (%)	Dehulled full-fat seed flour (%)	Protein concentrate (%)
Moisture	4·68 ± 0·04	4·15 ± 0·08	5·15 ± 0·09
Protein ($N \times 6{\cdot}25$)	28·6 ± 0·08	30·2 ± 0·12	76·5 ± 0·11
Fat	47·67 ± 0·11	54·16 ± 0·19	1·41 ± 0·03
Ash	3·49 ± 0·05	3·29 ± 0·08	2·06 ± 0·07
Fibre	4·51 ± 0·13	2·16 ± 0·17	2·23 ± 0·11
Carbohydrate (by difference)	11·1 ± 0·21	6·1 ± 0·33	12·6 ± 0·18

Values are means of at least triplicate determinations while errors are computed as standard errors.

Table 2. Some mineral contents of *Adenopus breviflorus* benth whole seed flour, and dehulled full-fat seed flour

Mineral	Whole seed flour (mg/100 g)	Dehulled full-fat seed (mg/100 g)
Sodium	100 ± 0·22	151 ± 0·25
Potassium	150 ± 0·17	150 ± 0·21
Calcium	90·5 ± 0·41	129 ± 0·85
Magnesium	2 120 ± 2·54	2 340 ± 1·96
Iron	8·55 ± 1·13	12·8 ± 1·57
Manganese	2·92 ± 0·07	3·90 ± 0·51
Phosphorus	146 ± 0·65	165 ± 0·75
Zinc	10·1 ± 1·02	4·89 ± 0·81
Copper	1·23 ± 0·05	1·01 ± 0·02

Values are means of at least triplicate determinations while errors are computed as standard errors.

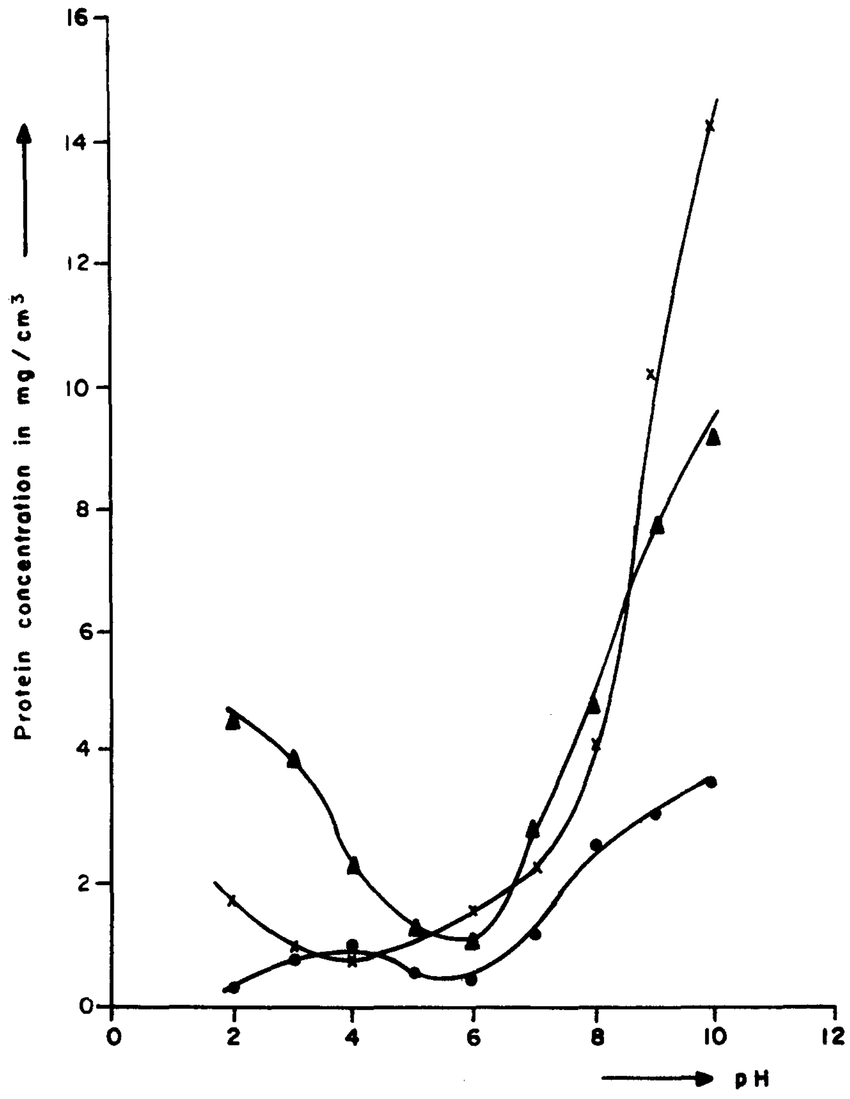

Fig. 1. Variation of protein solubility of *Adenopus breviflorus* benth flour. ●——● Whole seed flour with hull; ×——× seed flour without hull; ▲——▲ defatted seed flour without hull (protein concentrate).

acidic and basic pH regions. The seed flour with hull shows a maximum and a minimum solubility in the acid region while its solubility increases with pH in the basic region. The low solubility of the protein of seed flour with hull, at almost all pHs compared with flour without hull, may be an indication that the hull is inhibiting the solubility of the protein and this may occur when the seeds are consumed with the hull, as some consumers do, and may affect the maximum body utilization of the protein from this seed. The dehulled full-fat seed flour shows a minimum solubility at about pH 4·0 and its protein solubility in the acid region is very low compared with the basic region. This pattern is similar to those of some other oilseeds reported earlier by Lawhon *et al.* (1972), Cherry *et al.* (1979), Akobundu *et al.* (1982) and Ige *et al.* (1984). The figure further indicates that the protein concentrate has a minimum solubility at a pH of about 6·0 and its protein is soluble in both the acidic and basic pH regions. The higher solubility of this defatted seed flour sample at acid pH indicates that the proteins of this seed, after defatting, may be used in the formulation of acid foods such as milk analogue products and protein-rich carbonated beverages (Kinsella, 1979).

The results obtained for the other functional properties determined are shown in Table 3. The water absorption capacities of the *Adenopus breviflorus* benth materials depend on the types of product. The water absorption of the whole seed flour is 175·0% while those of the dehulled full-fat seed flour and the protein concentrate are 112·5 and 201·5%, respectively. The water absorption capacity of 112·5% obtained for the dehulled full-fat seed flour is lower than that of soy flour (130%), but higher than that of sunflower (107·1%) (Lin *et al.* 1974). This trend is also observed for the protein concentrates of soy and sunflower for which the water absorption capacities are 227·3 and 137·8%, respectively (Lin *et al.*, 1974) while, from Table

Table 3. Water and oil absorptions, gelation, emulsion and foaming capacities of *Adenopus breviflorus* benth flour

Functional properties	Whole seed flour (%)	Dehulled full-fat seed flour (%)	Protein concentrate (%)
Water absorbed	175·0+0·05	112·5+0·11	201·5+0·07
Oil absorbed	206·7+0·16	125·9+0·08	175·7+0·12
Least gelation concentration	16·00 (w/v)	14·00 (w/v)	10·00 (w/v)
Emulsion capacity	20·46+0·24	35·81+0·19	62·54+0·21
Foaming capacity	21·50+0·08	8·02+0·05	17·57+0·07
Foaming stability (2h after)	8·21+0·06	4·15+0·04	9·50+0·09

Values are means of at least triplicate determinations while errors are computed as standard errors.

3, the value obtained for *Adenopus breviflorus* benth protein concentrate is 201·5%. These trends suggest that the soy proteins are most hydrophilic, followed by the *Adenopus breviflorus* benth protein, while the sunflower protein is the least hydrophilic of the three.

The oil absorption capacities of the *Adenopus breviflorus* benth whole seed flour, dehulled full-fat seed flour and the protein concentrate are 206·7, 125·9 and 175·7%, respectively. The value of 125·9% oil absorption of the dehulled full-fat seed flour is higher than the values of 84·2 and 84·4% reported for wheat and soy flour, respectively, but lower than 207·8% reported for sunflower (Lin *et al.*, 1974). The oil absorption obtained for the protein concentrate of *Adenopus breviflorus* benth is 175·7% which is higher than the value reported for soy protein concentrate (133·0%) (Lin *et al.*, 1974) suggesting that *Adenopus breviflorus* benth may be more lipophilic than the soy protein concentrate. The oil absorption capacity reported for sunflower protein concentrate is 254·9% (Lin *et al.*, 1974). These values of oil absorptivities show a reverse trend compared with water absorptivities.

The least gelation concentrations (w/v) for *Adenopus breviflorus* benth whole seed flour, dehulled full-fat seed flour and protein concentrate are 16, 14 and 10% (w/v), respectively. The least gelation concentration of 14% (w/v) for the dehulled seed flour is the same as that for Lupin seed (Sathe *et al.*, 1982), but higher than those of Great Northern bean flour of 10% (w/v) (Sathe & Salunkhe, 1981), and pigeon pea of 12% (w/v) (Oshodi & Ekperigin, 1989). The least gelation concentration for its protein concentrate (10%, w/v) is higher than those for Great Northern bean protein concentrate (8%, w/v) (Sathe & Salunkhe, 1981), and Lupin seed protein concentrate (8%, w/v). It has been suggested (Sathe *et al.*, 1982) that variation in the gelling properties of different legume flours may be linked to the relative ratios of different constituents—proteins, carbohydrates and lipids—and that interactions between such components may affect functional properties. This may be the case in the observed least gelation concentration of the different *Adenopus breviflorus* benth flour in Table 3 as the three flours have different constituents in terms of protein, carbohydrates and fat (Table 1).

The results from the determination of emulsion capacity are also shown in Table 3. The value of 35·81% obtained for the dehulled full-fat seed flour almost doubles the value of 18% reported for soy flour and is triple the value of 11·7% for wheat, but is lower than the value of 95·10% recorded for sunflower flour by Lin *et al.* (1974). The emulsion capacity for the *Adenopus breviflorus* benth protein concentrate is 62·54% which is higher than the values of 2·80–25·20% reported for soy protein concentrates and 10·10–14·00% for sunflower protein concentrate reported by Lin *et al.* (1974).

The foaming capacity and the foaming stability of the flours are shown in Table 3. The foaming capacities are 21·50, 8·02 and 17·57% for whole seed flour, dehulled full-fat seed flour and dehulled defatted seed flour, respectively. The values of 8·02 and 17·57% are correspondingly lower than 70% reported for soy flour, and 230 and 220% reported for sunflower flours by Lin *et al.* (1974). The foaming stability of the *Adenopus breviflorus* benth protein concentrate is 9·50% after 2 h which is comparatively better than that of soy protein concentrate (5%) as reported by Lin *et al.* (1974) for the same time interval.

The results show that *Adenopus breviflorus* benth is nutritionally rich in fat, minerals and protein. The functional properties of the flours are comparatively good when compared with soy flour and some of the known seeds flours in use for food formulations. The functional properties are significantly improved when the flour is defatted, and this increases its potential for possible human food formulations.

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