Comparison of Physical, Chemical, and Functional Properties of *Moringa peregrina* (Al-Yassar or Al-Ban) and Soybean Proteins

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ABSTRACT

Flours of *Moringa peregrina* and soybean were individually defatted and fractionated into protein concentrate and protein isolate. *M. peregrina* flour was significantly ($P < 0.05$) higher in oil than soybean flour but lower in proteins, carbohydrates, and ash. *M. peregrina* protein concentrate also contained significantly lower protein levels and higher carbohydrate levels. The protein isolate of *M. peregrina* had higher protein levels and lower carbohydrate levels than the protein isolate of soy. Potassium and sodium were the predominant minerals in both *M. peregrina* and soy flour. X-ray diffraction patterns (d spacings and 2θ angle of crystallinity) could easily discriminate *M. peregrina* products from soybean products. *M. peregrina* flour and concentrate were significantly lower in bulk density than the soybean fractions. Polyacrylamide gel electrophoresis indicated 9 and 5 subunits (defatted flour), 13 and 9 subunits (protein concentrate), and 12 and 5 subunits (protein isolate) for soybean and *M. peregrina* proteins, respectively. *M. peregrina* proteins were somewhat less soluble than soy proteins, even at higher pH values. Emulsion capacity of *M. peregrina* products was generally higher than that of soybean products at all pH values, while emulsion stability of soybean products was generally higher, particularly at pH 2 and 10. Maximum increase in foam volume was observed at pH 2. At pH 4-6, the foam stability of *M. peregrina* protein isolate was greater, but the foam stability of its protein concentrate was lower than that of soybean proteins. Soy protein concentrate absorbed significantly more water, while *M. peregrina* products absorbed more oil.

Moringa peregrina (syns. = *M. optera* Gaertn., *M. arabica* (Lam.) Pers.) is one of about 10 xerophytic species of the family Moringaceae. English names include horseradish tree, oil of Ben tree, drumstick tree, and neverdie. French names include ben ailé and brede mornogy. This shrub or tree is 5-15 m high with greyish-green bark, long leaves (20-70 cm), and bisexual, yellowish white, showy, fragrant flours. *M. peregrina* is distributed throughout many countries from tropical Africa to the East Indies. In the northern and southern areas of Hejaz, Saudi Arabia, it is called *Al-Ban* or *Al-Yassar* (Migahid 1978, Somali et al 1984, FAO 1988). Young seeds are eaten as peas in India; mature seeds are fried or roasted like groundnuts in Malawi (FAO 1988). Its medical use, chemical composition, physicochemical characteristics, and fatty acid composition have been reported by several workers (Ageel et al 1984, Somali et al 1984, FAO 1988, Al-Yahya et al 1990). The seed kernel is rich in oil (42-54%), with up to 23% protein. Oleic acid is the main fatty acid (>70%).

The search for new protein sources is well established. Several legumes (mainly soybean) have been studied and proposed as protein alternatives for human consumption, particularly in developing countries. No information on *M. peregrina* proteins has been reported. Therefore, this study investigates the protein properties of *M. peregrina*, including some physical, chemical, and functional characteristics of defatted flour, protein concentrate, and protein isolate. Comparison was made with a well-known protein source, the soybean.

MATERIALS AND METHODS

Materials

Seeds (kernels) of *M. peregrina* were brought from the Al-Ola region of northwest Saudi Arabia. Soybeans (cv. Jupiter) were obtained from the Agricultural Experiment Station, College of Agriculture, King Saud University, Riyadh, Saudi Arabia. The seeds were cleaned, hand cracked, dehulled, and pulverized with a Waring commercial blender at speed 1 for 15 sec. The soybean seeds were milled to pass through a 0.5-mm sieve using an ultra-centrifugal mill (Resh ZMI, F. Kurt Retsch Gmb H & Co., Germany).

Preparation of Flours, Protein Concentrates, and Protein Isolates

The full-fat flours of *M. peregrina* and soybean were defatted with *n*-hexane for 16 hr using a Soxhlet apparatus. The defatted meals were air-dried for 24 hr at room temperature and then ground into flour (180-μm particles).

Protein concentrate was prepared according to the methods of Mattil (1974). Defatted flour was dispersed in 70% ethanol at a ratio of 1:10 (w/v) for 30 min with continuous stirring at room temperature before centrifugation at 3,000 rpm for 10 min. Supernatant was discarded. The precipitate was collected, dried at room temperature, and ground into flour (180-μm particles).

The laboratory procedure for preparing the protein isolates from *M. peregrina* and soybean defatted flours was based on the protein isolation method of Sosulski et al (1978). Defatted flour was first dispersed in water adjusted to pH 10 using NaOH (1.0*N*, 1:10 [w/v]) for 30 min with continuous stirring at room temperature. The second extraction used the same method at 1:5 (w/v). The combined extracts were adjusted to the pI with 0.2*N* HCl to precipitate the protein and centrifuged at 3,000 rpm for 10 min. The supernatant was discarded. The protein curd was spread as a thin layer on glass plates, air-dried, and ground into flour (180-μm particles).

Chemical Analysis

Moisture, protein (N × 6.25), fat, and ash were determined according to AOAC methods (1980). Total carbohydrates were calculated by difference. The atomic absorption spectroscopic method was used for analysis of calcium, potassium, iron, sodium, magnesium, copper, and zinc using an atomic absorption 1100B spectrophotometer (Perkin-Elmer Co., Gmbh-D7770, Uberlingen, Germany).

Bulk Density

Bulk density was determined by the method of Wang and Kinsella (1976). A preweighed, 100-ml graduated cylinder was filled to 100 ml with the sample. The sample was packed by gently tapping the cylinder on the bench top 10 times from a height of about 5 cm. The volume and weight were recorded. The bulk density was recorded as a ratio of weight (g) of sample to volume (ml).

X-Ray Diffraction

The X-ray diffraction patterns of the samples were determined using a Phillips fully automated X-ray diffraction spectrogoniometer (760 LEA, Almelo, Holland) equipped with a PW17 generator. Radiation was provided by a copper target (Cu anode, 2,000 W, 1.5418 Å). The X-ray beam was adjusted at 40 kV and 30 mA. The scanning speed of the goniometer was 0.02° at 2θ per second over the diffracted angle range (5-55°).

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Polyacrylamide Gel Electrophoresis

Polyacrylamide gel electrophoresis (PAGE) was performed according to the method of Laemmli (1970). Protein samples were prepared by mixing one part protein extract with three parts 0.05*M* Tris-HCl buffer (pH 6.8, containing 1% sodium dodecyl sulfate [SDS], 0.01% bromophenol blue, 30% glycerol, and 20 μl of mercaptoethanol). The samples were then heated at 95°C for 5 min and applied at 25–50 μl on a separating slab gel (15%, 1.5 mm thick) containing separator buffer (8 ml), acrylamide stock (pH 8.8, 16 ml), glycerol (0.5 ml), double-distilled H_2O (7.3 ml), tetramethylethylenediamine (14 ml), and 3.3% ammonium persulphate (160 ml). PAGE operated at 1 mA per sample until the bands entered the separating gel and then changed to 2 mA per sample until the end of the run, which took 8–10 hr at 4°C. The protein markers were phosphorylase (94.0 kDa), bovine serum albumin (65.0 kDa), ovalbumin (43.0 kDa), carbonic anhydrase (30.0 kDa), trypsin inhibitor (20.1 kDa), and α-lactalbumin (14.0 kDa). The gel was stained with 0.05% Coomassie Brilliant Blue R-250 and destained by diffusion in methanol, acetic acid, and water (50:10:40).

Protein Solubility

Protein solubility was determined according to the method described by King et al (1985) with a simple modification. Aqueous suspensions (1%) of each sample were prepared at pH values ranging from 2 to 10 using NaOH or HCl. The suspensions were magnetically stirred for 30 min and then centrifuged at 3,500 rpm for 30 min. The supernatant was decanted, filtered (Whatman no.4), and analyzed for protein content (N × 6.25) using the Kjeltec system (1,026 distilling unit, Prabin & Co-AB, Klippan, Sweden).

Emulsion Capacity and Stability

Emulsion capacity was evaluated in 100 ml of 1% (w/v) aqueous dispersion of each sample (pH 2–10) by titrating with corn oil to the breakpoint of the emulsion using a Waring blender at speed 2 (Marshall et al 1975). Emulsion capacity was expressed as grams of oil emulsified per gram of sample.

The emulsion was transferred to 250-ml graduated cylinders. The emulsion stability was recorded after 0.25, 0.50, 1, 2, 3, 24, and 48 hr at room temperature by noting the amount of water separated from the oil (Dipak and Kumar 1986).

Foaming Properties

Foaming capacity and foam stability were determined according to Dipak and Kumar (1986). One gram of each sample was whipped with 100 ml of distilled water at different pH ranges (2–10) for 5 min using a high-speed electric blender (Hamilton Beach) at speed 8 (whipping). Volume increase on whipping was measured. Foam capacity was expressed as a percentage of the original volume of the liquid. Foam stability was expressed as a percentage of the foam volume remaining in relation to initial foam volume at room temperature after 20, 40, 60, 90, and 120 min.

Oil and Water Absorption

For oil and water absorption determinations, the method of Beuchat (1977) was followed. One gram of sample was mixed with 10 ml of corn oil or distilled water for 30 sec in a 25-ml centrifuge tube. The samples were allowed to stand at room temperature for 30 min and then centrifuged at 1,500 rpm for 30 min. The volume of the supernatant was measured in a 10-ml graduated cylinder. Results were expressed as grams of corn oil or water absorbed per gram of sample.

RESULTS AND DISCUSSION

Composition

Proximate analysis data of *M. peregrina* and soybean seed products are summarized in Table I. The major component in *M. peregrina* flour was oil; the major component in soybean flour was total carbohydrate. Both *M. peregrina* and soy defatted flours were high in proteins and carbohydrates. *M. peregrina* protein concentrate was lower in proteins and higher in carbohydrates. However, its protein isolate contained higher protein (97.8%) than that of soybean. These results for soy flour, concentrate, and isolate are similar to previously reported values obtained by Ekpenyong and Borchers (1980), Narayana and Narasinga Rao (1982), and Foda et al (1984). Data on mineral content presented in Table II show that potassium is a predominant mineral in *M. peregrina* and soy flour and concentrate. Magnesium, followed by calcium, were the main minerals in both protein isolates. Moreover, sodium content in soy products was higher than that of *M. peregrina* products. However, variations in zinc and copper contents were relatively small among the tested samples.

TABLE I
Proximate Analysis of *Moringa peregrina* (M) and Soy (S) Products (% dwb)[a]

Product	Source	Moisture	Protein	Crude Oil	Ash	Carbohydrate[b]
Full fat flour	M	2.60 ± 0.01 b	23.8 ± 0.3 b	54.3 ± 0.4 a	3.06 ± 0.03 b	18.9 ± 0.6 b
	S	4.45 ± 0.04 a	32.8 ± 0.3 a	20.2 ± 0.2 b	6.07 ± 0.14 a	40.9 ± 0.4 a
Defatted flour	M	6.27 ± 0.03 b	57.1 ± 0.1 b	2.1 ± 0.09 a	6.17 ± 0.03 b	34.7 ± 0.1 a
	S	6.34 ± 0.01 a	58.1 ± 0.2 a	0.8 ± 0.02 b	6.66 ± 0.08 a	34.3 ± 0.2 b
Protein concentrate	M	4.55 ± 0.20 b	64.6 ± 0.4 b	0.75 ± 0.02 a	6.15 ± 0.08 a	28.6 ± 0.2 a
	S	4.77 ± 0.10 a	74.1 ± 0.2 a	0.52 ± 0.04 b	5.66 ± 0.01 b	19.8 ± 0.2 b
Protein isolate	M	3.45 ± 0.14 b	97.8 ± 0.2 a	0.52 ± 0.02 a	1.43 ± 0.28 b	0.3 ± 0.1 b
	S	6.86 ± 0.01 a	94.0 ± 0.1 b	0.19 ± 0.01 b	2.17 ± 0.09 a	3.7 ± 0.2 a

[a]Means (n = 2) for M and S for each product in the same column not followed by the same letter are significantly different from each other ($P < 0.05$) by Duncan's multiple range test.
[b]Calculated by difference.

TABLE II
Mineral Contents of *Moringa peregrina* (M) and Soy (S) Products (mg/100 g sample)[a]

Product	Source	K	Cu	Fe	Ca	Na	Zn	Mg
Full fat flour	M	486 ± 5 b	1.48 ± 0.45 a	1.30 ± 0.20 b	67.5 ± 3.8 b	1.30 ± 0.20 b	2.93 ± 0.44 b	212 ± 6 a
	S	1,366 ± 10 a	2.81 ± 0.06 a	5.92 ± 1.22 a	183 ± 3 a	70.7 ± 3 a	4.56 ± 0.30 a	230 ± 2 a
Defatted flour	M	742 ± 3 b	1.48 ± 0.06 a	19.5 ± 1.0 a	127 ± 1 a	23.1 ± 3.9 b	6.14 ± 0.24 a	225 ± 1 a
	S	1,170 ± 4 a	1.73 ± 0.33 a	8.34 ± 0.18 b	124 ± 2 a	43.8 ± 5.4 a	5.80 ± 0.01 a	214 ± 2 b
Protein concentrate	M	250 ± 4 b	2.08 ± 0.04 a	14.9 ± 0.2 a	149 ± 6 a	7.00 ± 2.76 b	10.8 ± 0.3 a	227 ± 4 a
	S	882 ± 5 a	1.76 ± 0.33 a	6.86 ± 0.15 b	132 ± 0.0 a	20.9 ± 1.4 a	4.63 ± 0.48 b	213 ± 1 b
Protein isolate	M	10.7 ± 0.3 b	6.65 ± 0.21 a	7.47 ± 0.55 a	111 ± 0.0 a	24.4 ± 2.9 b	1.49 ± 0.11 a	200 ± 0.0 a
	S	49.0 ± 1.8 a	3.55 ± 0.20 b	3.22 ± 0.01 b	112 ± 0.0 a	39.0 ± 0.9 a	2.45 ± 0.44 a	201 ± 0.0 a

[a]Means (n = 2) for M and S for each product in the same column not followed by the same letter are significantly different from each other ($P < 0.05$) by Duncan's multiple range test.

Generally, the mineral contents of soy products fall within the range of published values (Foda et al 1984).

Bulk Density

The bulk density of *M. peregrina* and soybean seed products are shown in Table III. Defatted soybean flour and concentrate were denser than those of *M. peregrina* products. The bulk density of *M. peregrina* protein isolate was similar to that of soybean isolate. Rahma and Narasinga Rao (1983) reported a bulk density of 0.29 g/ml for cottonseed defatted flour. Bulk densities of winged bean defatted flour (0.45 g/ml) and soybean defatted flour (0.46 g/ml) were reported by Dench (1982). Soybean protein concentrate bulk density was generally higher than that of *M. peregrina* (Table III). The bulk density of soybean protein concentrate was recorded as 0.52 g/ml by Wang and Kinsella (1976). These differences in bulk density for protein concentrates were most likely due to the method of drying the protein extract (Bryant et al 1988). The bulk density of food depends on combined effects of interrelated factors (intensity of attractive interparticle forces, particle size, number of contact points); a change in any one of the powder characteristics may result in significant change in the powder bulk density (Peleg and Bagley 1983). The commercial soybean protein concentrates were usually spray-dried, which yielded a denser product than freeze-drying. Spray-dried particles are usually small, which may give rise to increased bulk density (Bryant et al 1988). On the other hand, Dench (1982) reported bulk density for winged bean protein isolate (0.11 g/ml) and soybean protein isolate (0.31 and 0.33 g/ml). Changes in bulk density might result from moisture absorption, chemical reactions, or mechanical attrition (Peleg and Bagley 1983).

X-Ray Diffraction Patterns

X-ray diffraction analysis of *M. peregrina* and soybean fractions produced the X-ray diffraction patterns (Fig. 1). A long set of data (not shown) representing the *d* spacing as the distance from the origin of reciprocal space (distance is proportional to $1/d$ in real space) was determined. The scattering angle, at which the diffraction intensities can be observed, was 2θ. The individual diffraction intensities of crystal peaks were also determined. Such parameters are the resolution limits of the X-ray data (McPherson 1982). Due to the length of data, only the *d* spacings discriminating the crystal peaks are mentioned for each fraction. The *d* spacings for defatted *M. peregrina* flour were: 5.4, 4.2, 3.9, 3.2, 3.0, 2.8, 2.8, and 2.4 Å. The *d* spacings for defatted soybean flour were: 5.5, 4.9, 3.5, 3.3, 2.7, 2.5, 2.4, and 1.8 Å. The *d* spacings for for *M. peregrina* protein concentrates were: 6.0, 5.5, 5.2, 4.8, 4.2, 3.8, 3.3, 2.0, 1.9, 1.9, 1.7, and 1.7 Å. The *d* spacings for soybean protein concentrates were: 12.1, 9.2, 5.3, 4.6, 4.5, 4.3, 4.2, 3.6, 3.1, 2.9, 2.0, and 2.0 Å. *M. peregrina* protein isolate *d* spacings were: 7.2, 4.7, 4.6, 4.5, 4.4, 4.2, 4.1, 4.0, 2.7, 2.2, and 1.7 Å. The *d* spacings for soybean isolate were: 4.8, 4.7, and 4.1 Å. The *d* spacings are a principle step in the discrimination of planes of different sites (Sherwood 1976).

Generally, the X-ray diffraction patterns (Fig. 1) indicate the amorphous nature of *M. peregrina* and soybean fractions, with some crystal peaks discriminated by *d* spacing. However, up to 11 lines of crystals were found for *M. peregrina* protein isolate, compared to three lines for soy isolate. At low resolution (>4.0 Å Bragg spacings) about all that can be extracted from the density map is the gross three-dimensional form of molecules and, occasionally, large α-helices. At 3.2 Å or less, the polypeptide backbone may be displayed in two-dimensional form (McPherson 1982). The limit of resolution of the data gives a good measure of the homogeneity of the molecules and the precision of their packing in the lattice.

X-ray diffraction can show the crystalline structure of molecules and the presence of secondary structural elements, such as α-helices and β-sheets, and show how they are joined together (McPherson 1982). It is important to relate the X-ray diffraction data to protein functionality (solubility, emulsion stability, swelling foamability, foam stability) to predict the behavior of *M. peregrina* and soybean products in a food system. However, such information is not available, and more research is needed in this area.

TABLE III
Comparative Bulk Density of *Moringa peregrina* (M) and Soy (S) Products (g/ml)[a]

Product	Source	Bulk Density
Defatted flour	M	0.157 ± 0.005 b
	S	0.382 ± 0.003 a
Protein concentrate	M	0.462 ± 0.006 b
	S	0.632 ± 0.011 a
Protein isolate	M	0.677 ± 0.023 a
	S	0.678 ± 0.020 a

[a]Means ($n = 3$) for M and S for each product in the same column not followed by the same letter are significantly different from each other ($P < 0.05$) by Duncan's multiple range test.

PAGE

SDS-PAGE patterns of proteins of soybean and *M. peregrina* seed products are shown in Figure 2. Proteins of defatted soybean contained nine subunits, seven of which were predominant (90, 76, 56, 42, 38, 21, and 15 kDa), and those of *M. peregrina* flours had five predominant subunits (60, 38, 23.5, 19, and 13 kDa).

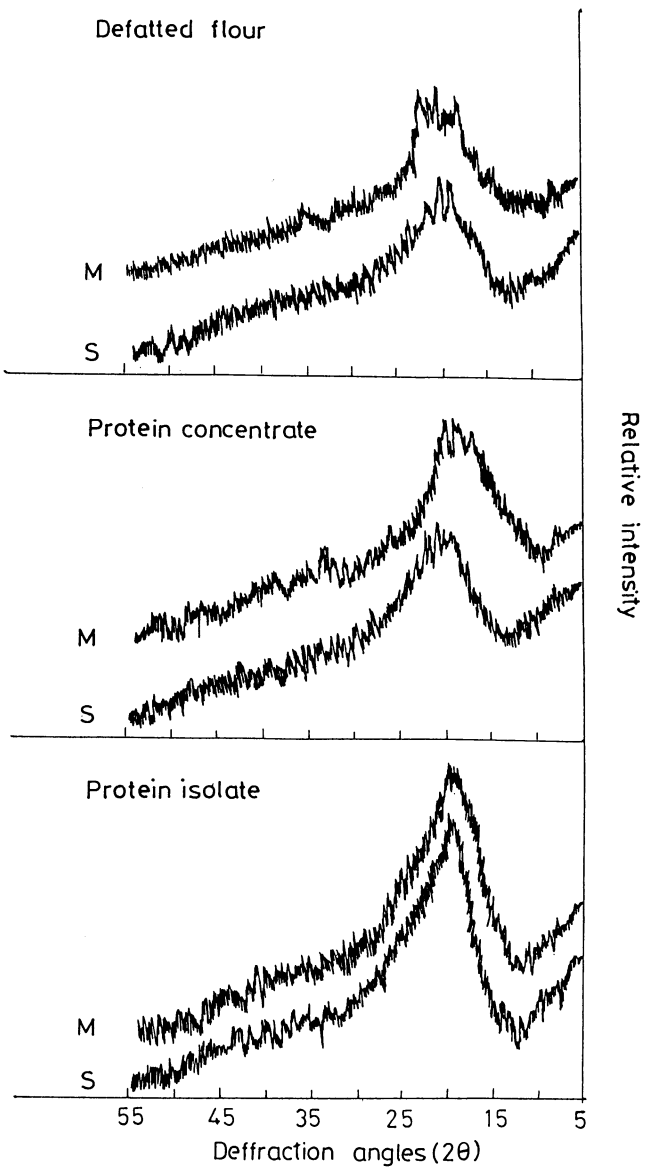

Fig. 1. X-ray diffraction patterns of *Moringa peregrina* (M) and soybean seed (S) products.

For protein concentrates and protein isolates, it appears that the major protein subunits are 11.5–60 kDa for *M. peregrina* and 13–90 kDa for soybean. The electrophoretic velocity (mobility of components) is dependent on several factors including pH of the buffer, retardation coefficient related to size and shape, ion interaction, charge, and structure in the neighborhood of charged particles or surfaces (Wolf 1977). Defatted four, protein concentrate, and protein isolate not only differ in number and type of components but also in degree of solubility, due to processing conditions. With this in mind, in addition to electrophoretic velocity factors, a change in electrophoretic pattern is expected when going from defatted flour to protein concentrate and then to protein isolate.

Soybean proteins were intitially classified according to ultracentrifugal analysis into 2S, 7S, 11S, and 15S fractions (Naismith 1955, Wolf and Briggs 1956). Other nomenclature was developed and proposed, but Catsimpoolas (1969) used the names glycinin, α-, β-, and γ-conglycinin. One recent characterization of soy storage proteins, published by Brooks and Morr (1985), referred to 11S glycinin, 7S β-conglycinin, and γ-conglycinin and their subunits.

Protein Solubility

Protein solubility profiles of *M. peregrina* and soybean products are shown in Figure 3. Minimum protein solubility for both sources occurred between pH 4 and 4.5, the apparent pI region. As expected, the protein solubility increased at pH values on each side of the pI region. The defatted soybean flour was generally more soluble than the defatted *M. peregrina* flour across the pH range. The protein of *M. peregrina* concentrate was more soluble at acidic pH than at alkaline or neutral pH; the protein of soybean concentrate was more soluble at alkaline pH than at acidic or neutral pH (Fig. 3). On the other hand, *M. peregrina* isolate was more soluble than soybean isolate at all pH values, except pH 8–10. These protein solubility curves are very similar to those of other plant protein flour and protein concentrates (McWatters and Holmes 1979; Dench 1982; Narayana and Narasinga Rao 1982; Sathe et al 1982a,b) and plant protein isolates (Volkert and Klein 1979, Dench et al 1981, King et al 1985).

Protein solubility is very complex and can be affected by many variables such as electrostatic interactions, hydrophobic interactions, and hydrogen bonding. The levels of these three major forces contribute to protein solubility by favoring protein-protein interactions (indicated by lower protein solubility) or by favoring protein-solvent interactions (indicated by higher protein solubility) (Kinsella et al 1985).

The low solubility of *M. peregrina* might adversely affect its functional properties. However, there are means of modifying these properties: by pH, with and without the presence of various salts (Mattil 1971); by improvement of isolation methods; by chemical means (Groninger 1973); and by enzyme treatment (Puski 1975).

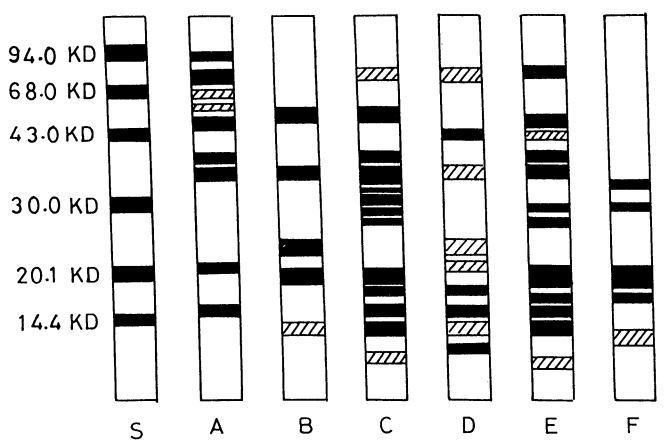

Fig. 2. Sodium dodecyl sulfate-polyacrylamide gel electrophoresis profiles of *Moringa peregrina* and soybean seed products. **S,** standard; **A,** soybean defatted flour; **B,** *M. peregrina* defatted flour proteins; **C,** soybean protein concentrate; **D,** *M. peregrina* protein concentrate; **E,** soybean protein isolate; **F,** *M. peregrina* protein isolate. Solid bands = high intensity. Striped bands = low intensity.

Emulsion Capacity and Stability

The effect of pH on the emulsification capacity of *M. peregrina* and soybean seed products is shown in Figure 4. The emulsion capacity values for *M. peregrina* products (defatted flour, protein concentrate, and protein isolate) were generally higher than those of the corresponding soybean products at all the pH values studied. At pH 4 and 4.5, (minimum solubility), the respective emulsification capacities for *M. peregrina* and soybean seed products were 55–80 and 20–50 grams of oil per gram of sample. With increase of pH, emulsification capacity of *M. peregrina* increased to a maximum at pH 8 for defatted flour, and it continued increasing for protein concentrate and protein isolate. The maximum emulsification capacity of soybean products is in agreement with those reported by Crenwelge et al (1974) and Narayana and Narasinga Rao (1982). The emulsion capacity versus pH profile of both *M. peregrina* and soybean seed products closely resembled the protein solubility in shape, suggesting that emulsification was caused by the solubilized proteins. In the case of soybean (Crenwelge et al 1974), groundnut (Ramanathan et al 1978), and

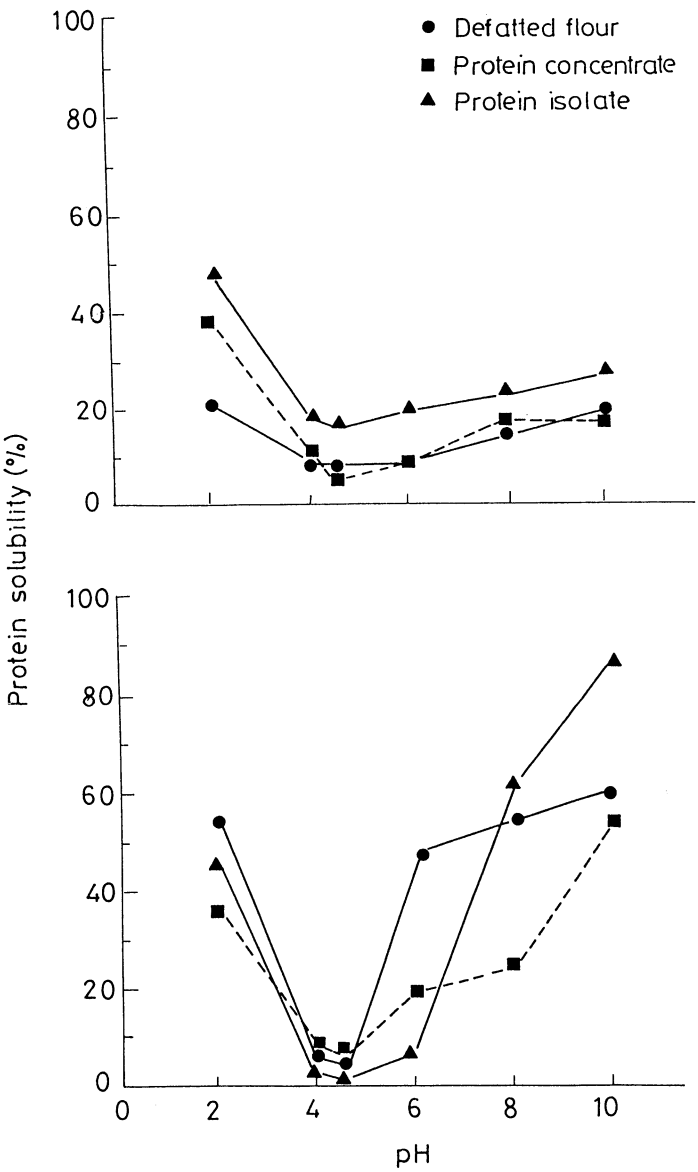

Fig. 3. Protein solubility of *Moringa peregrina* (top) and soybean (bottom) seed products.

guar proteins (Nath and Narasinga Rao 1981), a similar relationship between emulsification capacity and pH has been reported. Dependence of emulsion capacity on pH was expected; emulsion capacity of soluble proteins depends upon the hydrophilic-lipophilic balance (Sosulski 1977), which is affected by pH. Similar observations on the relationship of pH and emulsifying capacity of proteins have been reported by several investigators (Lin et al 1974, Canella et al 1979, Lah and Cheryan 1980).

Emulsion stability of soybean products over the 48-hr test period was generally higher than that of *M. peregrina* products, particularly at pH 2 and 10 (Table IV–VI). The results on soybean proteins are in agreement with those of Foda et al (1984). Emulsion stability is important because the success of an emulsion depends on its ability to maintain the emulsion in subsequent processing steps (Wolf and Cowan 1975). Soybean flour and isolates are excellent emulsifiers and binders in high-fat foods, and this characteristic has been associated with their high water- and fat-absorption properties (Porteous and Wood 1983, Mittal and Usborne 1985).

It is very important to know how the proteins interact and function in the finished product. The complexity of *M. peregrina* and soybean proteins indicates they may undergo a wide range of reactions in food systems. Further studies are needed on their reactions with constituents like water, lipids, and starch before explaining such properties as water and fat absorption and gelation of foods (Wolf 1970).

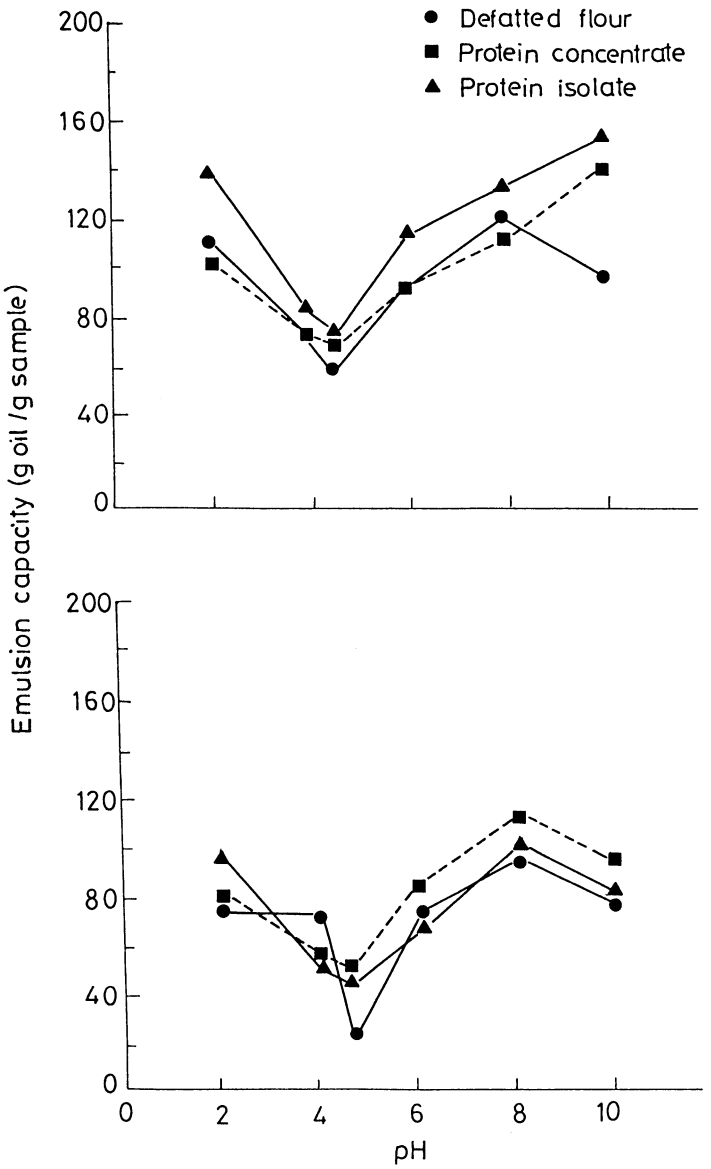

Fig. 4. Emulsion capacity of *Moringa peregrina* (top) and soybean (bottom) seed products.

Foaming Properties

Foam capacities of *M. peregrina* and soybean products are presented in Figure 5. Foaming was pH-dependent. At pH 4.5, the apparent isoelectric pH of the proteins, minimal foaming was observed for all products. Among the defatted flours, the maximum increase in volume was 470% at pH 8 and 460% at pH 2 for *M. peregrina*. It was 405% at pH 10 and 400% at pH 2

TABLE IV
Effect of pH on Emulsion Stability[a] of Defatted *Moringa peregrina* (M) and Soy (S) Flour[b]

		Time, hr						
pH	Source	0.25	0.5	1.0	2.0	3.0	24.0	48.0
2.0	M	55	60	68	74	78	80	84
	S	0	0	0	0	0	0	0
4.0	M	70	74	80	84	86	90	90
	S	38	52	65	72	74	75	80
4.5	M	76	78	84	84	86	90	90
	S	68	74	80	82	82	83	85
6.0	M	70	78	86	88	90	90	90
	S	30	35	50	54	60	60	70
8.0	M	40	68	72	80	84	86	90
	S	0	0	0	5	10	12	50
10.0	M	20	68	78	90	94	94	98
	S	0	0	10	15	28	34	70

[a]Volume (ml) of water separated at room temperature (22°C).
[b]Mean of duplicate determination.

TABLE V
Effect of pH on Emulsion Stability[a] of *Moringa peregrina* (M) and Soy (S) Protein Concentrates[b]

		Time, hr						
pH	Source	0.25	0.5	1.0	2.0	3.0	24.0	48.0
2.0	M	50	58	80	86	90	90	90
	S	0	0	0	0	0	0	0
4.0	M	80	90	92	94	96	96	98
	S	80	94	100	100	100	100	100
4.5	M	80	90	94	95	96	98	98
	S	90	94	98	98	98	98	98
6.0	M	20	60	76	86	90	90	94
	S	80	88	92	94	94	94	94
8.0	M	40	56	80	86	90	90	90
	S	15	25	36	50	55	60	72
10.0	M	30	30	70	70	80	80	90
	S	0	0	0	0	10	10	44

[a]Volume (ml) of water separated at room temperature (22°C).
[b]Mean of duplicate determination.

TABLE VI
Effect of pH on Emulsion Stability[a] of *Moringa peregrina* (M) and Soy (S) Protein Isolates[b]

		Time, hr						
pH	Source	0.25	0.5	1.0	2.0	3.0	24.0	48.0
2.0	M	0	0	0	0	0	0	0
	S	0	0	0	0	0	0	0
4.0	M	62	70	76	90	90	90	93
	S	90	98	98	100	100	100	100
4.5	M	80	86	90	90	90	95	95
	S	90	94	98	98	98	98	98
6.0	M	10	30	80	90	90	90	95
	S	50	84	90	92	94	94	96
8.0	M	80	90	90	90	92	94	94
	S	70	90	92	94	96	96	96
10.0	M	25	60	82	90	92	92	92
	S	0	0	0	0	0	0	0

[a]Volume (ml) of water separated at room temperature (22°C).
[b]Mean of duplicate determination.

for soybean flour. The highest foam increase for *M. peregrina* and soybean concentrates was obtained at pH 2, which revealed higher foaming capacity (430%) at pH 2 than at the corresponding value (375%) for *M. peregrina* concentrate. On the other hand, *M. peregrina* protein isolate exhibited high foaming capacity (430%) only at pH 2, while soybean isolate had high foam capacity at pH 2 and 10 (375 and 400%, respectively). Similar trends (higher foaming at about pH 2 and 8) were observed by Cherry and McWatters (1981) for glandless cottonseed flour. They attributed the optimum foaming properties of glandless cottonseed flour at pH 1.5 and 11.5 to the dissociated proteins and increased solubility of major storage globulins at these pH values. Such pH dependence on foaming characteristics was also reported for soybean and sunflower proteins (Lin et al 1974, Hermansson 1975).

Sosulski and McCurdy (1987) reported that protein isolates from soybean and faba bean formed less foam on whipping than did the corresponding flour, probably because of the loss of soluble, low molecular weight proteins during aqueous processing. This finding agreed with our results for soybeans.

Foam stability of *M. peregrina* and soybean products over a 2-hr time period are given in Table VII. Defatted *M. peregrina* flour was more stable at pH 4 and 8, while defatted soybean flour was more stable at pH 4.5 and 6. Sosulski et al (1976a) observed a decrease of 18.2–38.6% in foam volumes of 10 legume flours over 2 hr. Soybean retained a higher foam volume over the 2-hr period than did any other legume flour.

For protein concentrates, maximum foam stability was observed at pH 2 and 4.5 for soybean and at pH 2 for *M. peregrina* (Table VII). However, foaming stability of *M. peregrina* concentrate was much lower than that of soybean at pH 6.

Maximum foam stability of protein isolates (Table VII) was observed at pH 2 for soybean and pH 10 for *M. peregrina*. The foam of soybean isolate collapsed completely after only 20 min at pH 4.5, after 90 min at pH 4, and after 120 min at pH 6. At these pH values, foam stability of *M. peregrina* isolate decreased by 52.6, 54.7, and 70.7% in the same pH order. The high stability of foams in the acid pH range observed in the this investigation may have been due to the formation of stable molecular layers in the air-water interface that impart texture, stability, and elasticity to the foams. This molecular stabilizing effect in acidic pH was also reported by Cherry and McWatters (1981).

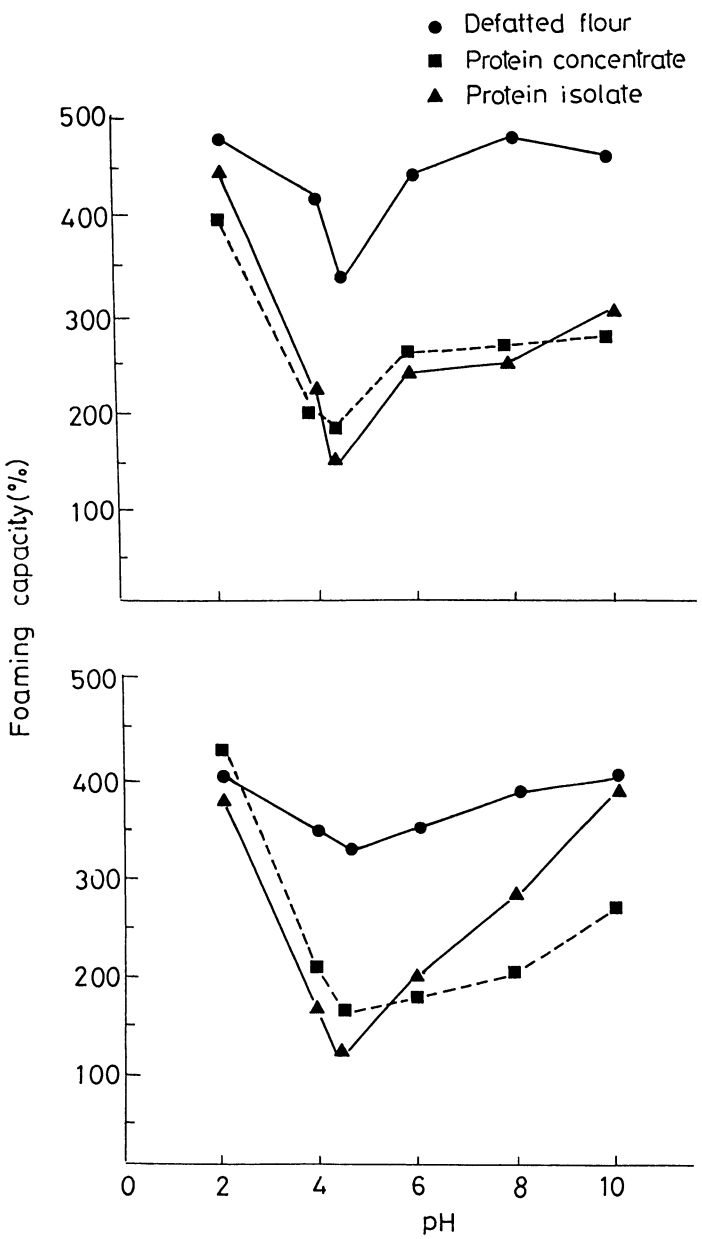

Fig. 5. Foaming capacity of *Moringa peregrina* (top) and soybean (bottom) seed products.

Oil and Water Absorption

Oil and water absorption capacities values of *M. peregrina* and soybean fractions are given in Table VIII. *M. peregrina* fractions had higher oil absorption than the soybean fractions did. Oil absorption for *M. peregrina* in this study was higher than that for peanut (Beuchat 1977), rapeseed (Sosulski et al 1976b), and soybean flour (Sosulski and McCurdy 1987). The oil absorption values of soybean protein isolate were similar to that obtained by Sosulski and McCurdy (1987).

Oil absorption is mainly attributed to the physical entrapment of oil (Kinsella 1976). It is also related to the number of nonpolar side chains on proteins that bind hydrocarbon chains on the fatty acids. Lin et al (1974) observed that sunflower proteins were more lipophilic than soy proteins, and they concluded that sunflower

TABLE VII
Effects of pH on Decrease in Foam Stability[a] (% over 2 hr) of *Moringa peregrina* (M) and Soy (S) Protein Products[b]

pH	Source	Defatted Flour	Protein Concentrate	Protein Isolate
2.0	M	93.8	24.4	64.0
	S	49.4	30.4	15.7
4.0	M	50.0	60.0	54.7
	S	53.6	53.2	100
4.5	M	70.0	46.2	52.6
	S	32.5	29.3	100
6.0	M	92.2	90.0	70.0
	S	27.9	36.0	100
8.0	M	39.1	51.7	63.8
	S	33.8	58.3	45.5
10.0	M	78.9	76.2	34.7
	S	67.1	35.2	24.4

[a] Measured as volume (ml) of water separated at room temperature (22°C).
[b] Mean of duplicate determination.

TABLE VIII
Oil and Water Absorption Capacity (g/g) of *Moringa peregrina* (M) and Soy (S) Seed Products[a]

Products	Source	Oil Absorption Capacity	Water Absorption Capacity
Defatted flour	M	3.0 ± 0.01 a	2.6 ± 0.03 a
	S	2.4 ± 0.02 b	2.2 ± 0.01 b
Protein concentrate	M	3.1 ± 0.00 a	3.0 ± 0.02 b
	S	2.2 ± 0.03 b	4.0 ± 0.01 a
Protein isolate	M	2.4 ± 0.01 a	2.2 ± 0.00 a
	S	1.3 ± 0.02 b	2.1 ± 0.04 b

[a] Means ($n = 3$) for M and S for each product in the same column not followed by the same letter are significantly different from each other ($P < 0.05$) by Duncan's multiple range test.

proteins contained more nonpolar side chains, which retained oil by associative binding.

Water absorption of soybean protein concentrate in this investigation was higher than that of *M. peregrina* protein concentrate (Table VIII). Variations in the water absorption values were relatively small among the samples of defatted flours and protein isolates for both *M. peregrina* and soybean. The results of this study were in agreement with results obtained by Sosulski and Fleming (1977) for soybean flour and concentrates. Increased water absorption by soybean products with increased protein contents was reported by Fleming et al (1974). However, water absorption of a particular sample need not be parallel to its protein content. Lin et al (1974) observed that all sunflower products had lower water absorptions than those of soybean products, although their protein contents were similar. Total water absorption increases with increasing protein concentration, and water absorption without protein dissolution results in swelling. However, no consistent relationship exists between protein solubility and water absorption. Water absorption variations among the tested samples may be related to the nature and type of proteins. Hydrophilic properties of proteins are related to such polar groups as carbonyl, hydroxyl, amino, carboxyl, and sulfhydryl. Water-binding capacity varies with the number and type of polar groups (Kuntz 1971). Moreover, the increased water absorption of the defatted products may have been due to exposure of water-binding sites on side chains of proteins previously blocked in a lipophilic environment. Water binding by proteins is influenced by the physicochemical environment (Chou and Morr 1979). The higher water-binding capacities of the tested samples may be important to properties such as swelling, solubility, viscosity, and gelation.

Soybean proteins have great potential as functional agents in fabricated foods and supplements in the diet of undernourished people, particularly in the developing countries. Although the *M. peregrina* products in this study show some comparable functional properties, they can not be recommended until other studies, including nutritional properties, toxicities, antinutritional components (inhibitors, phytic acid, polyphenol), determine its suitability for humans or livestock. Such studies are underway and will be published separately.

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