

PHYSICO-FUNCTIONAL PROPERTIES OF PEANUT MEAL FLOUR AS AFFECTED BY PROCESSING METHODS

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ABSTRACT

Cold- and heat-pressed peanut meal cakes were milled, defatted and ground into fine powder and evaluated for proximate composition and functional food properties. Flours contained over 50% protein as compared with 25–45% protein in peanut meal cake. Cold-pressed peanut meal flour (CPMF) had a solubility profile similar to heat-pressed peanut meal flour (HPMF), with minimum and maximum solubility observed at pH 3.5–5.0 and pH 10.0 and higher, respectively. HPMF exhibited relatively high functional properties (emulsification, stability, oil and water absorption, whipping) compared with CPMF and commercial soy flour. Results suggest that flour obtained from peanut meal can be used as emulsifiers in different food formulations. Peanut flour could be a good source of food formulation for different food products in developing countries. Results show that high temperatures and long-time pressing affected physicochemical and functional properties of peanut flour.

PRACTICAL APPLICATIONS

Physico-functional properties of peanut meal cake, a waste product from peanut oil processing, were evaluated. Findings indicated that processing methods had significant effect on the physicochemical and functional

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characteristics of peanut flour. However, functional properties such as emulsification, heat stability, oil and water absorption, whipping and foamability were identified as useful attributes for application of peanut flour in a variety of food formulations. The protein content of peanut flour can serve as a cheap source of protein in developing countries where protein-energy malnutrition is prevalent. Recent research has suggested the possibility of using peanut oil as an alternative diesel fuel source. This is bound to increase the volume of peanut cake. Considering the high cost of conventional animal protein sources, the protein content of the cake could be tapped for human consumption. This research is environmentally friendly as it aims at converting waste product into functional food ingredients.

INTRODUCTION

Peanut has found many uses besides serving directly as food. It is used as a source of cooking oil, animal feed and by-products used as shaving cream, metal polish, bleach, ink, soap, shampoo, explosives, paint, rubber, axle grease, paper, wallboard, fireplace logs, cat litter and medicine (Abulude *et al.* 2006). Vegetable oil extraction from peanut yields partially defatted peanut flour (PDPF). PDPF is a protein-rich, low fat, inexpensive and under-utilized by-product of the peanut industry that offers the same health and dietary benefits as peanut. PDPF contains 47–55% high-quality protein with high essential amino acid content that could be easily employed in a variety of food applications (Ahmed and Schmidt 1979). The development of peanut flour from defatted peanut meal cake can also provide the food industry with a new cost-effective and high-protein food ingredient for product formulation. This is critically needed in many developing countries where protein-energy malnutrition remains a major health hazard, especially among children. Functional properties of defatted peanut meal flours are also important in food processing and food product formulation. Some of these include: whipping properties, emulsification, bulk density, viscosity, water and oil absorption (Yu *et al.* 2007). These properties are affected by the intrinsic factors of protein such as molecular structure and size, and many environmental factors including the processing and production methods and the presence of other components in the food system (Basha and Pancholy 1982). The importance of these properties varies with the type of food products in which the flour is used. For example, flours with high oil and water absorption capacities are desirable for use in meats, sausages, breads and cakes, while flours with high emulsifying and whipping properties are good for salad dressing, sausages, bologna, soups, confectioneries, frozen desserts and cakes (Davis *et al.* 2007). Literature and/or appropriate references on the development and functionality of peanut

meal flour as affected by processing methods are difficult to come by. Therefore, the objectives of this study were to (1) develop meal flour from peanut oil processing by-product; (2) determine its functional properties as indicators of its potential use by the food industry; and (3) evaluate the effects of processing methods on its functionality.

MATERIALS AND METHODS

Materials and Reagents

Cold-pressed peanut meal cake (CPMC), cream colored and prepared without any heat treatment, and heat-pressed peanut meal cake (HPMC), brown in color and prepared by steaming at 120C for 40 min, baked at 130C for 20 min and extruded at 120C, were purchased from Qingdao Kerry Peanut Oil Co., Ltd. (Shandong province, China). Commercial soy flour (CSF) was purchased from the Qin Shan Wan local market, Wuxi City, China. All chemicals used were of reagent grade and obtained either from other laboratories or from the chemical department of Southern Yangtze University, Wuxi, China.

Pretreatment of Samples

Both CPMC and HPMC were further defatted using petroleum ether at temperatures ranging from 30 to 60C using the Soxhlet method for 8 h. Defatted samples were air dried, milled into fine powder using an HR2839 model Philip blender, sieved to pass through a 70 mesh, oven dried for 3 h at 40C and stored at 4C in refrigerator until ready for analysis.

Determination of Functional Properties of Peanut Meal Flour

Functional properties evaluated were protein solubility, water and fat absorption properties, emulsifying and whipping properties, bulk density, viscosity and gelation.

Flour Solubility. To determine flour solubility, a modified form of the method described by Peredes-Lopez and Ordorica-Falonic (1986) was used. Each defatted peanut meal flour, cold-pressed peanut meal flour (CPMF) (flour obtained from CPMC) and heat-pressed peanut meal flour (HPMF) (flour obtained from HPMC), was mixed with water in the ratio of 0.05 g/1.0 mL (w/v), and pH of the mixture adjusted to 2.0–10.0 using 0.1 M NaOH and HCl. The peanut flour suspension was stirred at room temperature for 1 h, and then centrifuged at $3,000 \times g$ for 15 min. Protein concentration in each supernatant (soluble protein) was determined by micro-Kjeldahl (AOAC methods 1990)

using 5.46 as conversion factor. The soluble protein content was calculated as gram soluble protein per 100.0 g flour based on the weight of flour used and supernatant obtained after centrifugation.

Water Absorption Capacities. For the determination of water absorption capacities of samples, the method explained by Sosulski (1962) was used. In addition, 1.0 g of each sample (CPMF, HPMF and CSF) was transferred into 15.0 mL centrifuge tube. Also, 10.0 mL of distilled water was added to each sample, at the same time washing down the inside of the centrifuge tube. Using a glass stirring rod, the flour and water were mixed for 30 s with sufficient vigor to bring all the flour into suspension. The suspension was allowed a 10-min rest, during which time the flour adhering to the side of the centrifuge tube was scrubbed down with glass rod to prevent it from drying. Several additional mixings of sufficient duration were made so as to bring all the flour into suspension (20 s), with 10-min rest periods following each mixing. The suspension was centrifuged at $3,500 \times g$ for 15 min. The supernatant liquid was decanted and the centrifuge tube was placed mouth down at an angle of 15° to 20° in a forced-draft oven. The tubes were allowed to drain and dry for 25 min at 50°C , cooled in desiccators and weighed. The percentage water absorption was calculated by the constant flour weight procedure using the following equation:

$$\% \text{ water absorption} = (x + y - 5)20$$

where x is increase in weight of flour, in g; y is weight of flour used, in g (100.0).

Oil Absorption Capacities. Fat absorption capacities of flours were determined by using a modified form of the method described by Lin *et al.* (1974). One gram of each sample was weighed into a 15.0-mL centrifuge tube, and 10.0 mL of pure soybean salad oil (produced by East Ocean Oils and Grains Industries, Zhang Jiagang, Jiangsu Province, China) was added and content was thoroughly mixed for 5 min, held at room temperature for 1 h and then centrifuged ($2,500 \times g$ for 15 min). The excess oil was poured off and the tube was inverted for 30 min. The weight of oil retained was calculated as g oil bound g^{-1} sample $\times 100\%$. Estimation was performed in triplicate.

Emulsifying Capacities and Stability. Emulsifying properties (EP) and emulsion stability were determined according to the methods of Pearce and Kinsella (1978) and Matusdomi *et al.* (1994). For the determination of EP, emulsions of oil (pure soybean salad oil produced by East Ocean Oils and Grains Industries) and 0.1% of samples of peanut flours, soy flour and gum

acacia powder (a commonly used emulsifier in foods that was used as a control) were formed in a ratio of 1:3, respectively. The solutions were shaken and homogenized in an HR2839 Philip blender (using the highest speed) for 1 min at room temperature. Aliquots of 100 μ L were measured from the bottom of the emulsion after standing for 0, 1, 3, 7, 10, 15, 20, 25, 30 min/s and diluted with 5.0 mL of 0.1% sodium dodecyl sulfate solution. The absorbance of the diluted solution was measured at 500 nm. The emulsifying activity was determined from the absorbance measured immediately after emulsion formation (0 min). For the determination of emulsion stability, each of the emulsions under test was held at constant temperatures of 40, 60 and 80C in a temperature-control water bath while being gently stirred. Periodically, aliquots of the emulsions were taken for dilution and measurements of emulsion stability as described above.

Whipping Properties. Whipping properties of 3% dispersions of CPMF, HPMF and CSF were determined in triplicate using a modified form of the method described by Lin *et al.* (1974). Samples (5.0 g) were dispersed in distilled water (125.0 mL) and pH adjusted to 7.0 using 0.1 M NaOH and HCl. The suspensions were thereafter homogenized for 1 min at maximum speed using an HR2839 model Philip blender and pH was checked and adjusted when necessary.

Suspensions were then whipped, using maximum speed in a Kenwood Chef Food mixer for 10 min with the wire whip attachment. The resulting foam was immediately poured into a liter-measuring cylinder and the foam height was measured at intervals.

The percent foam expansion was calculated as follows:

$$\% \text{ vol. increase} = \frac{A - B}{B} \times 100$$

where *A* is the volume after whipping and *B* is the volume before whipping. Foam volume as percentage was calculated taking the foam volume at zero time as 100%. Leakage was calculated as follows:

$$\text{leakage} = \frac{C}{D} \times 100$$

where *C* is the volume of liquid collected and *D* is the volume of liquid before whipping.

Viscosity and Gelation Properties. The method of Sathe and Salunkhe (1981) as described by Ihekoronye (1986) was used for the determination of

viscosity. An appropriate sample was dispensed in distilled water and magnetically stirred for 2 h at room temperature prior to viscosity measurement. Each sample was at concentrations of 10, 20, 30, 40, 50, 70 and 100 g/L and viscosity was measured at room temperature using an Ostwald-type viscometer. Determination of gel strength was carried out at varying sample concentrations of 10, 20, 30, 40, 50, 60, 70 and 100 g/L in 5.0 mL distilled water. The test tubes containing these varying suspensions were heated for 1 h in a boiling water bath followed by rapid cooling under running cold tap water. The minimum gelling concentration was determined as that in the sample which did not fall down or slip when the tube containing it was inverted.

Bulk Density. The bulk densities of CPMF, HPMF and CSF were determined in triplicate using the method of Wang and Kinsela (1976). A 10.0-mL graduated cylinder was initially weighed and then filled to 5.0 mL with sample powder by constant tapping until there was no further change in the volume. Its weight was then recorded and from the difference in weight, bulk density was calculated.

Proximate Composition Analysis

Total protein content of peanut flour was evaluated using a Kjeldahl nitrogen analyzer and a conversion factor of 5.46. Fat, moisture and ash were determined using standard AOAC methods 932.06, 925.09 and 923.03, respectively (AOAC methods 1990).

Data Analysis

Data were analyzed by analysis of variance using SAS (SAS 2002).

RESULTS

Peanut Flour Solubility

The solubility curves for HPMF, CPMF and CSF follow almost the same trend as shown in Fig. 1. The least solubility for the three samples under discussion occurred between pH 3.5 and 5.0. However, at all pH levels, HPMF was relatively more soluble than both CPMF and CSF.

Water and Oil Absorption Properties

Water and oil absorption properties are presented in Table 1. It could be clearly seen from Table 1 that HPMF had slightly higher water and oil absorption capacities than CPMF and CSF.

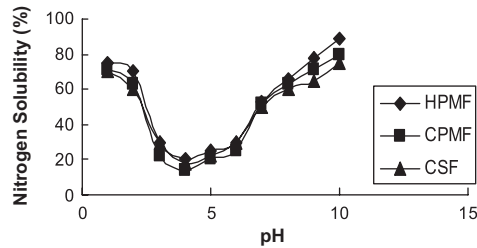


FIG. 1. SOLUBILITY CURVES FOR COLD-PRESSED PEANUT MEAL FLOUR (CPMF), HEAT-PRESSED PEANUT MEAL FLOUR (HPMF) AND COMMERCIAL SOY FLOUR (CSF)

TABLE 1.
COMPARATIVE ANALYSIS OF SOME FUNCTIONAL PROPERTIES OF HPMF,
CPMF AND CSF

Sample	Functional attribute*		
	Fat absorption (%)	Water absorption (%)	Bulk density g/mL
CPMF	84.01 $\pm$ 0.30	87.01 $\pm$ 0.10	0.40 $\pm$ 0.03
HPMF	89.80 $\pm$ 0.10	93.40 $\pm$ 0.71	0.41 $\pm$ 0.04
CSF	83.33 $\pm$ 0.04	88.55 $\pm$ 0.33	0.41 $\pm$ 0.02

* All experiments were conducted in triplicates.

CPMF, cold-pressed peanut meal flour; HPMF, heat-pressed peanut meal flour; CSF, commercial soy flour.

EP

HPMF exhibited a relatively higher EP than CPMF, CSF and gum acacia (Fig. 2). CSF demonstrated the least EP. Results obtained from the analysis of heat stability of HPMF, CPMF and CSF show that all samples were thermodynamically unstable at all temperature levels tested in this work (Fig. 3). However, HPMF was comparatively more stable at almost all temperature levels.

Whipping Properties

The parameters evaluated under whipping properties were foam expansion, foam volume and leakage (Table 2). Results obtained show that HPMF recorded slightly higher values for the three parameters tested. Results also show that both foam volume and leakage were time dependent. CSF recorded more favorable whipping properties than CPMF.

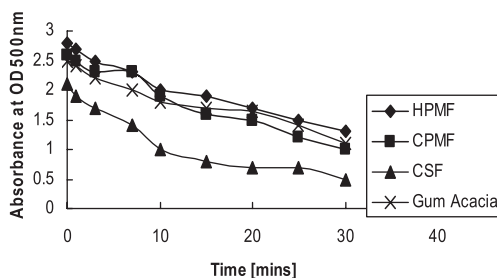


FIG. 2. EMULSIFYING PROPERTIES OF COLD-PRESSED PEANUT MEAL FLOUR (CPMF), HEAT-PRESSED PEANUT MEAL FLOUR (HPMF), COMMERCIAL SOY FLOUR (CSF) AND GUM ACACIA

Viscosity and Gelability

Data obtained for both viscosity and gelation are presented in Table 3. Viscosity had a direct relationship with gel formation as higher viscosity values recorded higher gel formation. Gelation occurred earlier in HPMF and CSF as compared with CPMF.

Biochemical Scores of HPMF and CPMF

Biochemical scores for HPMF and CPMF are presented in Table 4. CPMF has higher protein, fat and carbohydrate contents as compared with HPMF.

DISCUSSION

Peanut Flour Solubility

Flour solubility is considered a key functional property because it influences other functional properties. In water, the flour slurry gives a pH of 6.5–7.0 and over 80% of proteins dissolve. If the pH is lowered progressively, less protein is dissolved and extractability reaches a minimum in the range pH 3.5–5.0, which is the isoelectric region for a bulk of proteins. Similar results were obtained in the solubility study of the protein components of the flours tested. Heat processing method employed in extraction of peanut meal has both positive and negative effects on peanut flour. Heating destroys antimegaloblasts such as trypsin and amylase inhibitors in legumes, thus improving bioavailability or digestibility of protein content of flours (Snyder and Kwon 1987). Heating also adds pleasant flavor/aroma and color to peanuts and makes them palatable. Patil *et al.* (1993) reported that heat treatment can have a

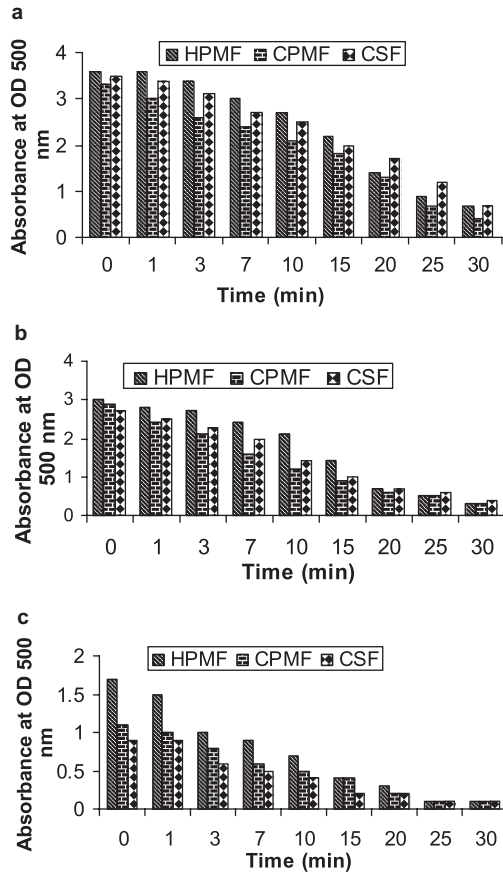


FIG. 3. (a) HEAT STABILITIES OF COLD-PRESSED PEANUT MEAL FLOUR (CPMF), HEAT-PRESSED PEANUT MEAL FLOUR (HPMF) AND COMMERCIAL SOY FLOUR (CSF) AT 40°C. (b) HEAT STABILITIES OF CPMF, HPMF AND CSF AT 60°C. (c) HEAT STABILITIES OF CPMF, HPMF AND CSF AT 80°C

significant effect on the functional properties of peanut meal cake. Solubility of CPMF, HPMF and CSF significantly decreased in the pH range 3.5–5.0 (Fig. 1). As shown in Fig. 1, HPMF had relatively higher protein solubility than CPMF and CSF. This is in agreement with the findings of Patil *et al.* (1993) who reported that heating full-fat peanut seed in water at 100–120°C for 15 min increased solubility. However, the effect of heating resulted in minimal difference in solubility between CPMF and HPMF. This could be probably attributed to the high pressing temperatures and longer pressing times which may have resulted to an increased surface hydrophobicity of the protein

TABLE 2.
WHIPPING PROPERTIES OF HPMF, CPMF AND CSF

Sample	Foam expansion (%)	Foam volume (%)				Leakage (%)		
		Over time (min)						
		1	10	30	60	90	30	90
CPMF	76.10 ± 0.44	74.3 ± 0.30	71.7 ± 0.10	58.1 ± 0.21	30.4 ± 0.02	22.5 ± 0.33	22.02 ± 0.01	46.03 ± 0.10
HPMF	88.32 ± 0.02	80.4 ± 0.03	76.1 ± 0.11	66.3 ± 0.13	30.3 ± 0.31	16.1 ± 0.41	17.20 ± 0.10	47.22 ± 0.11
CSF	86.41 ± 0.30	78.2 ± 0.33	76.5 ± 0.31	68.1 ± 0.23	35.1 ± 0.01	24.4 ± 0.13	20.04 ± 0.13	46.04 ± 0.30

CPMF, cold-pressed peanut meal flour; HPMF, heat-pressed peanut meal flour; CSF, commercial soy flour.

TABLE 3.
VISCOSITY AND GELATION PROPERTIES OF CPMF, HPMF AND CSF

Sample concentration (%)	Viscosity (Cps) [†]			Gel strength		
	HPMF	CPMF	CSF	HPMF	CPMF	CSF
1	2.21	2.03	2.14	NG	NG	NG
2	2.54	2.29	2.40	NG	NG	NG
3	2.93	2.66	2.58	N*	N*	N*
4	3.62	2.89	2.88	N*	N*	N*
5	3.81	2.97	3.11	N*	N*	N*
6	3.95	3.22	3.38	N**	N**	N**
7	4.01	3.51	3.77	N***	N**	N**
8	4.33	3.83	3.84	N***	N**	N**
9	4.41	3.99	4.00	N****	N***	N****
10	4.55	4.23	4.30	N****	N****	N****

[†] Mean values of five experiments.

CPMF, cold-pressed peanut meal flour; HPMF, heat-pressed peanut meal flour; CSF, commercial soy flour; NG, no gelation; N*, negligible gel formation; N**, weak gel; N***, fairly strong gel; N****, strong gel.

TABLE 4.
BIOCHEMICAL SCORES OF HPMF AND CPMF (%)

Sample	Protein	Moisture	Fat	Carbohydrate	Ash	Crude fiber
HPMF	49.8	5.9	0.9	24.8	8.6	8.0
CPMF	52.1	7.1	1.6	23.5	7.6	9.7

CPMF, cold-pressed peanut meal flour; HPMF, heat-pressed peanut meal flour.

content of the flour thereby leading to the unfolding of molecules upon exposure to high temperatures (Abulude *et al.* 2006).

Water and Oil Absorption Properties

Interactions of water and oil with flours are very important in food systems because of their effects on the flavor and texture of foods. Intrinsic factors affecting water-binding properties of food flours with relatively high protein contents include amino acid composition, protein conformation and surface polarity/hydrophobicity (Barbut 1999). However, food processing methods are bound to have significant impact on flour conformation and hydrophobicity. Studies have also shown that hydrophobicity of amino acid side chains within polypeptides are dependent upon the chemical microenvironment of the interface established between the solute, solvent and the

hydrocarbonaceous ligand. Furthermore, the polarity or nonpolarity of amino acids represents an important biological consequence of the hydrophobic effect and application in food science. Results obtained in this study show that heating reduced both water and oil absorption properties of HPMF (Table 1). Nevertheless, values obtained for these parameters were still minimally higher than those obtained for CPMF and CSF. During oil extraction, using the heat-pressed method, proteins in peanut meal cakes were likely denatured by high temperature and longer pressing times, thereby exposing more hydrophobic sites, which explain the relatively reduced water retention capacity of HPMF. As shown in Table 1, the decreased oil absorption property of HPMF could be attributed to a likely occurrence of an irreversible denaturation caused by heating at high temperatures which might have destroyed both hydrophilic and hydrophobic groups of proteins in HPMF, thus reducing both water and oil absorption properties. This agrees with the findings of Yu *et al.* (2007). Also, the amino acid profiles obtained for CPMF and HPMF (result not presented in this study) show that HPMF contained more nonpolar amino acids (alanine, isoleucine, phenylalanine) than CPMF. Considering the low solubility of nonpolar molecules in water, the results in Table 1 could be fully understood. This is consistent with the findings of Shanmugasundaram and Venkataraman (1989) and Kinsella (1979). Bulk density is important for determining packaging requirements, material handling and application in wet processing in the food industry. Bulk density is generally affected by particle size. Because the same blender and blending speed were used to mill all samples, bulk densities are bound to be almost the same as shown in Table 1. This means that the milling method did not have any significant effect on the bulk density of peanut flours evaluated.

EP

EP are usually attributed to the flexibility of solutes (i.e., the ability to go into solution and adsorb into interfaces) and exposure of hydrophobic domains. Food emulsions are thermodynamically unstable mixtures of immiscible liquids (water and oil). The formation and stability of emulsion are very important in food systems such as salad dressing. Proteins in flours are composed of charged amino acids, noncharged polar amino acids and nonpolar amino acids, which make high-protein flours potential choice of emulsifiers, the surfactant possessing both hydrophilic and hydrophobic properties and have the characteristic to interact with both water and oil in food system, Monteiro and Prackash (1994). HPMF demonstrated higher EP compared with CPMF, CSF and gum acacia (Fig. 2). This difference in EP may have been due to the different processing methods. The effect of high temperatures and longer

heating times on the emulsifying capacity of the peanut flour might be balanced by the increase in surface hydrophobicity and decrease in solubility of peanut proteins, hence the relatively low EP demonstrated by HPMF. Results obtained also show that CPMF, HPMF and CSF exhibited thermodynamically unstable characteristics when exposed to varying temperatures of 40, 60 and 80C (Fig. 3). However, at all temperature levels, as seen in Fig. 3, HPMF was relatively more stable than CPMF and CSF.

Whipping Properties

The formation of foam is analogous to the formation of emulsion. In the case of foam, water molecules surround air droplets, and air is the nonpolar phase. Theoretically, the amphipathic character of protein makes them good foaming agents that work at air–water interface to prevent bubble coalescence (Yasumatsu *et al.* (1972)). HPMF is a good foaming agent compared with CPMF and CSF (Table 3). However, it only exhibited slightly higher foaming characteristics compared with the other samples under discussion. Heating of peanuts during processing probably reduced the foam expansion and foam volume of HPMF (Abulude *et al.* 2006). Therefore, HPMF recovered from heat-pressing method with temperatures between 120 and 140C and relatively shorter pressing times may be suitable in food systems that require foaming such as cake and ice cream. On the other hand, flours obtained at high pressing temperatures (>140C) and longer extraction times have relatively low foaming capacity.

Viscosity and Gelability

Viscosity is considered an important attribute of foods because it affects mouthfeel. According to Myers *et al.* (1994), protein content in flour affects both viscosity and gelability. Protein conformation, disulfide linkages, hydrophobicity, etc. have all been reported to play significant roles in gelation. As could be seen from Table 4, HPMF demonstrated higher viscosity than CPMF and CSF. HPMF formed an early increased gel strength compared with CPMF and CSF. This may have occurred as a result of the formation of a protein–polysaccharide conjugate through protein–polysaccharide interaction which consequently increased the tendency of gelling macromolecules to cross-link, thereby resulting in increased gel strength (Davis *et al.* 2007). The biochemical scores for HPMF and CPMF are shown in Table 4. It could be clearly seen that during the heat-pressing method, some of the proteins were denatured due to high temperature, hence the low protein content reported for HPMF as compared with CPMF.

CONCLUSION

Peanut flour obtained from by-product of peanut oil production (peanut meal) has been found to possess essential functional food properties. The functionality of peanut flours is primarily dependent on their degree of solubility. Flours with high oil and water absorption capacities are desirable for use in meats, sausages, breads and cakes, while those with high emulsifying capacity are good for sausages, bologna, soups and salad dressing. HPMF showed better functional properties, particularly, water-holding and emulsifying capacity, than CPMF. Thus, peanut flours have the potential to add value to the peanut industry and provide food processors with affordable source of food plant with desirable extrinsic and intrinsic food properties and functional characteristics. Above all, it could also be environmentally friendly as it aims at converting waste groundnut meal cake, expelled during oil extraction, into an active food ingredient.

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