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# Effects of Processing Methods on the Physico-Functional Properties of Peanut Flour (*Arachis hypogaea* L.)

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**Abstract:** Cold and heat pressed peanut meal cakes were milled, defatted, grind into fine powder and evaluated for proximate composition and functional food properties. Flours contained over 50% protein as compared to 25-45% protein in peanut meal cake. Cold Pressed Peanut Flour (CPPF) had a solubility profile similar to Heat Pressed Peanut Flour (HPPF), with minimum and maximum solubility observed at pH 3.5-5.0 and pH 10.0 and higher, respectively. Both CPPF and HPPF exhibited relatively high functional properties compared to gum acacia and commercial soy flour. Results suggest that flour obtained from peanut meal can be used in food formulations requiring high emulsifying capacity. 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 physico-chemical and functional properties of peanut flour. The physico-functional properties of peanut meal cake, a waste product from peanut oil processing, were evaluated. Findings indicated that the processing method (cold and heat pressed) had a significant effect on the physico-functional attributes 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 meal flour in a variety of food formulations. As a result of its high protein content the flour can serve as a cheap source of protein particularly in developing countries where protein-energy malnutrition is prevalent. This research is also environmentally friendly as it aims at converting a waste product into a functional food ingredient.

**Key words:** Peanut meal cake, heat pressing, cold pressing, functional properties

## INTRODUCTION

Peanut has traditionally been used as a source of oil. However, its worldwide annual protein harvest has increased tremendously in recent years. Most peanuts grown are used for oil production, peanut butter, confectionaries and snack products (Hinds, 1995). 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 (with the exception of a few) 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 mal-nutrition remains a major health hazard, especially among children. Functional properties of defatted peanut meal flours are important in food processing and food product formulation. Some of these include; whipping properties, emulsification, bulk density, viscosity, water and oil absorption. 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; Bland and Lax, 2000). 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 suitable for salad dressing, sausages, bologna, soups, confectioneries,

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frozen desserts and cakes. 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 develop a flour from peanut oil processing by-product, to determine its functional properties as indicators of its potential use by the food industry and to evaluate the effects of processing methods on its functionality.

## MATERIALS AND METHODS

**Materials and reagents:** Cold pressed peanut cake (CPPC) and heat pressed peanut cake (HPPC) were purchased from Qingdao Kerry Peanut Oil Co., Ltd. (Shandong province-China).

All chemicals used, were of reagent grade and obtained either from other laboratories or from the chemical department of Southern Yangtze University, Wuxi, P.R. China.

**Pre-treatment of samples:** Both CPPC and HPPC were further defatted using petroleum ether at temperatures ranging from 30 ~ 60°C 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 40°C and stored at 4°C in refrigerator until ready for analysis. The flours obtained from both CPPC and HPPC are referred to as cold pressed peanut flour (CPPF) and heat pressed peanut flour (HPPF), respectively.

**Determination of functional properties of CPPF and HPPF:** Functional properties evaluated were flour solubility, water and fat absorption properties, emulsifying and whipping properties, bulk density, viscosity and gelation.

**Flour solubility:** To determine protein solubility, a modified form of the method described by Peredes-Lopez and Ordorica-Falonic (1986) was used. Each defatted peanut flour (CPPF, HPPF and Commercial Soy Flour-CSF) was mixed with water in the ratio of 0.5 g/10.0 mL (w/v) and pH of the mixture adjusted from 2.0-10.0 using 0.1 M NaOH and HCl. Suspensions of CPPF and HPPF were stirred at room temperature for 1 h and then centrifuged at 3000 x g for 15 min. Protein concentration in each supernatant (soluble protein) was determined by micro-Kjeldahl method (AOAC method, 1990) using 5.46 as conversion factor.

The soluble protein content was calculated as gram soluble protein per 100 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 CPPF, HPPF and CSF, the method described by Sosulski (1962) was used.

**Oil absorption capacities:** Fat absorption capacities of CPPF and HPPF 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 mL centrifuge tube and 10 mL of pure soybean salad oil (produced by East Ocean Oils and Grains Industries, Zhang Jiagang, Jiangsu Province, P.R. China) was added and content thoroughly mixed for 5 min, held at room temperature for 1 h and then centrifuged (2500 x g for 15 min). The excess oil was poured off and the tube inverted for 30 min. The weight of oil retained was calculated as g oil bound $g^{-1}$ sample × 100%. Estimations were performed in triplicate.

**Emulsifying capacities and stability:** Emulsifying properties and emulsion stability were determined according to the methods of Pearce and Kinsella (1978) and Matusdomi *et al.* (1994).

**Whipping properties:** Whipping properties of 3% dispersions of CPPF, HPPF and CSF were determined in triplicate using a modified form of the method described by Lin *et al.* (1974). Samples (5 g) were dispersed in distilled water (125 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 HR 2839 model Philip Blender and pH 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 measured at intervals. The percent foam expansion was calculated as follows:

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

Where:

A = Vol. after whipping
B = Vol. 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 = Vol. of liquid collected

D = Vol. 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.

**Bulk density:** The bulk densities of CPPF and HPPF were determined in triplicate using the method described Wang and Kinsela (1976).

**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 contents were determined using standard AOAC methods 932.06, 925.09 and 923.03, respectively (AOAC, 1990).

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

## RESULTS

The solubility chart for HPPF, CPPF and CSF follow similar trend as shown in Fig. 1. The least solubility for the three samples under discussion occurred between pH 3.5-5.0. However, at all pH levels, HPPF was relatively more soluble than both CPPF and CSF.

It could be clearly shown from Table 1 that HPPF had slightly higher water and oil absorption capacities than CPPF and CSF.

HPPF exhibited a relatively higher emulsifying property than CPPF and gum acacia (Fig. 2). Results obtained from the analysis of heat stability of HPPF, CPPF and gum acacia show that all samples were thermodynamically unstable at all temperature levels tested in this study (Fig. 3a-c).

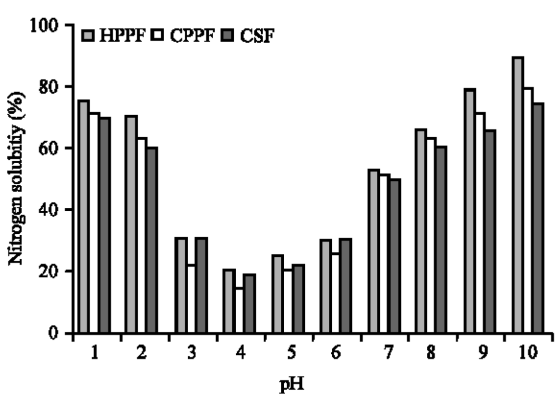


Fig. 1: Solubility of CPPF, HPPF and CSF

Table 1: Fat absorption, water absorption and bulk density of HPPF, CPPF and CSF

| Samples | Functional attribute[§] Fat absorption (%) | Water absorption (%) | Bulk density (g mL$^{-1}$) |
|---|---|---|---|
| CPPF[1] | 84.01±0.30 | 87.01±0.10 | 0.40±0.03 |
| HPPF[2] | 89.80±0.10 | 93.40±0.71 | 0.41±0.04 |
| CSF[3] | 83.33±0.04 | 88.55±0.33 | 0.41±0.02 |

[1]: Cold pressed peanut meal flour; [2]: Heat pressed peanut meal flour; [3]: Commercial soy flour; [§]: All experiments were conducted in triplicates

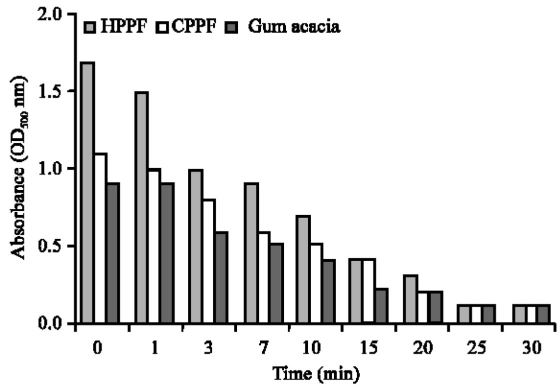


Fig. 2: Emulsifying properties of CPPF, HPPF and gum acacia

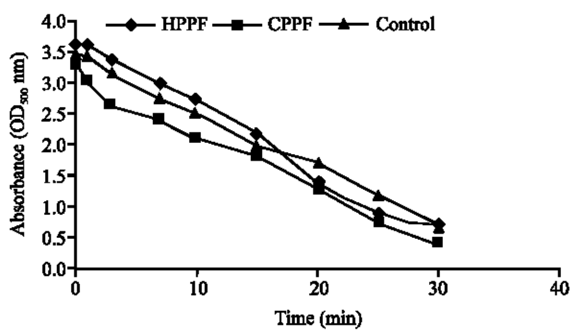


Fig. 3a: Heat stabilities of CPPF, HPPF and control (Gum acacia) at 40°C

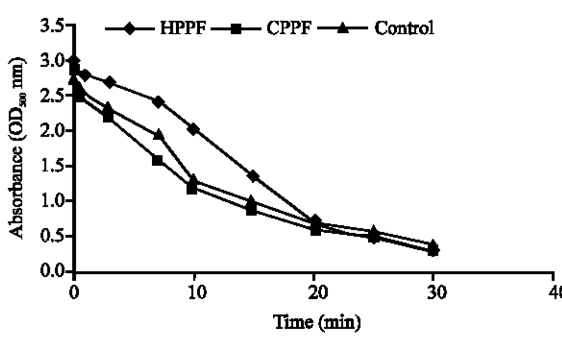


Fig. 3b: Heat stabilities of CPPF, HPPF and control (Gum acacia) at 60°C

Table 2: Whipping properties of HPPF, CPPF and CSF

| Samples | Foam expansion (%) | Foam volume (%) over time (min) 1 | 10 | 30 | 60 | 90 | Leakage (%) 30 | 90 |
|---|---|---|---|---|---|---|---|---|
| CPPF[1] | 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 |
| HPPF[2] | 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[3] | 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 |

[1]: Cold pressed peanut meal flour; [2]: Heat pressed peanut meal flour, [3]: Commercial soy flour

Table 3: Viscosity and gelation properties of CPPF, HPPF and CSF

| | Viscosity (Cps)[1] | | | Gel strength | | |
|---|---|---|---|---|---|---|
| Sample concentration (%) | HPPF | CPPF | CSF | HPPF | CPPF | 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 | NG | NG | NG |
| 4 | 3.62 | 2.89 | 2.88 | NG | NG | NG |
| 5 | 3.81 | 2.97 | 3.11 | NG | NG | NG |
| 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*** |

NG: No gelation; N*: Weak gel; N**: Fairly strong gel; N***: Strong gel, [1]: Mean values of five experiments

Table 4: Biochemical scores of HPPF and CPPF (%)

| Sample | Protein | Moisture | Fat | Carbohydrate | Ash | Crude fiber |
|---|---|---|---|---|---|---|
| HPPF [1] | 49.8 | 7.3 | 0.9 | 24.8 | 8.6 | 8.9 |
| CPPF[2] | 52.1 | 7.1 | 1.5 | 22.5 | 7.4 | 9.2 |

[1]: Heat pressed peanut flour; [2]: Cold pressed peanut flour

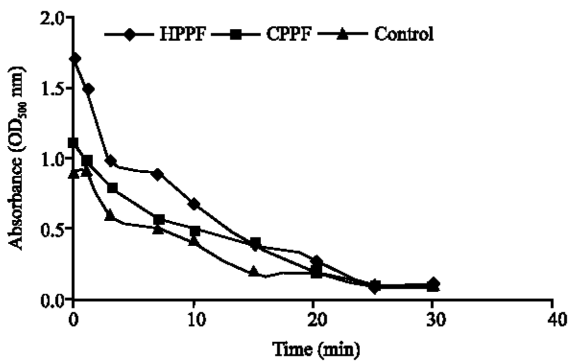


Fig. 3c: Heat stabilities of CPPF, HPPF and control (Gum acacia) at 80°C

Results obtained show that HPPF recorded slightly higher values for the three parameters tested. Results also show that both foam volume and leakage were time dependent (Table 2).

Viscosity had a direct relationship with gel formation as higher viscosity values recorded higher gel formation (Table 3). Gelation occurred earlierin HPPF and CSF as compared to CPPF.

CPPF has higher protein, fat and carbohydrate contents as compared to HPPF (Table 4).

## DISCUSSION

**Peanut flour solubility:** CPPF and HPPF have high protein contents. Among the functional properties of high-protein flours solubility is of primary importance due to its significant influence on other functional properties such as foam formation, gelation, emulsion and whipping properties (Halling, 1981). In water, the flour slurry gives a pH of 6.5-7.0 and over 80% of proteins can dissolve within this pH range. 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 (Morr and Ha, 1993). Similar results were obtained in the solubility study of CPPF and HPPF. Heat pressed method employed in the extraction of HPPF has both positive and negative effects on HPPF. Heating destroys anti-metabolites 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 colour to HPPF and makes it palatable. Petil *et al*. (1993) reported that heat treatment can have negative effects on the functional properties of high-protein flours. Solubility of CPPF, HPPF and CSF significantly decreased in the pH range 3.5-5.0 (Fig. 1). As shown in Fig. 1, HPPF demonstrated relatively higher solubility than CPPF and CSF. This is in agreement with the findings of Petil *et al*. (1993) who reported that heating full fat peanut seed in water at 100-120°C for 15 min increased solubility. 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 content of HPPF thereby leading to the unfolding of molecules upon exposure to high temperatures (Yu *et al*., 2007).

**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, 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 non-polarity 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 HPPF (Table 1). During oil extraction, using the heat pressed method, proteins in HPPF were likely denatured by high temperature and longer pressing times, thereby exposing more hydrophobic sites, which explain the relatively reduced water retention capacity of HPPF. The decreased oil absorption property of HPPF 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 HPPF, thus reducing both water and oil absorption properties (Table 1). Also the amino acid profiles obtained for CPPF and HPPF (result not presented in this study) show that HPPF contained more non-polar amino acids (alanine, isoleucine, phenylalanine) than CPPF.

Considering the low solubility of non-polar 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. Since 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 processing methods did not have any significant effect on the bulk density of CPPF and HPPF.

**Emulsifying properties:** Emulsifying properties 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.

Proteinaceous food systems (such as high protein flours) are composed of charged amino acids, non-charged polar amino acids and non-polar 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). HPPF demonstrated slightly higher emulsifying properties (EP) compared to CPPF 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 pressing times on the emulsifying capacity of HPPF might be balanced by the increase in surface hydrophobicity and decrease in solubility of peanut proteins.

Results obtained also show that CPPF, HPPF and gum acacia exhibited thermodynamically unstable characteristics when exposed to varying temperatures of 40, 60 and 80°C (Fig. 3c). However, at all temperature levels, as shown in Fig. 3c, HPPF was relatively more stable than CPPF and gum acacia.

**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 non-polar phase (Gonzalez-Perez *et al*., 2005). Theoretically the amphipathic character of proteinaceous food substances makes them good foaming agents that work at air-water interface to prevent bubble coalescence, Yatsumatsu *et al*. (1972). CPPF is a good foaming agent compared to HPPF and CSF (Table 3). However, it only exhibited slightly higher foaming characteristics compared to the other samples under discussion Heating of peanuts during processing probably reduced the foam expansion and foam volume of HPPF. Therefore, CPPF recovered from cold pressed method 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 (>140°C) and longer extraction times have relatively low foaming capacity.

**Viscosity and gelability:** Viscosity is relevant from a food perspective because it is an important functional property of foods and by understanding how biopolymer concentration, shape, size and polydispersity affect viscosity is industrially vital to food processors. Besides, viscometric measurements on food biopolymers, either in highly purified form or in controlled mixtures of highly purified materials, allow us to probe fundamental molecular properties of food macromolecules, such as conformation in dilute solutions, molecular weight, molecular weight distribution and interaction properties. It is important in providing physical stability to emulsions and other suspended particles and contributes to the mouth feel of foods.

According to Myers *et al.* (1994), protein content in high-protein flours affects both viscosity and gelability. Protein conformation, disulphide linkages and hydrophobicity, have all been reported to play significant roles in gelation (Moure *et al.*, 2006). As could be seen from Table 4, HPPF demonstrated higher viscosity than CPPF and gum arabic. HPPF formed an early increased gel strength compared to CPPF and gum arabic. 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. The biochemical scores for HPPF and CPPF are shown in Table 4. It could be clearly seen that during the heat pressed method some of the proteins were denatured due to high temperature, hence the low protein content reported for HPPF as compared to CPPF.

## CONCLUSION

Peanut flour obtained as by-product from 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. HPPF and CPPF showed desirable functional properties.

Thus, peanut flours have the potential to add value to the peanut industry and provide food processors with affordable source of food with desirable extrinsic and intrinsic 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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