Functional Properties of Sorghum-Peanut Composite Flour

U. SINGH and B. SINGH[1]

ABSTRACT

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Raw and heat-processed partially defatted peanut flour, sorghum flour, and their composite flour had different functional properties (water and oil absorption, viscosity, gelation, emulsion capacity, nitrogen solubility index [NSI] and protein dispersibility index). Water and oil absorption increased with heat processing; this effect was more pronounced in peanut than in sorghum flour. Sorghum flour samples attained a viscosity peak of 630 BU when raw and 438 BU when heat-processed. Peanut fortification reduced the viscosity peak of sorghum flour. The NSI and emulsion capacity of sorghum flour improved considerably as a result of fortification. Heat-processing reduced the NSI and emulsion capacity of peanut flour and peanut-fortified sorghum flour. The implication of these results will be realized in designing protein-enriched products based on sorghum flour, especially for sorghum-growing regions of the world.

Millions of people in Asian and African countries eat sorghum (*Sorghum bicolor* L.) as a staple food. The peanut (*Arachis hypogeae* L.), also known as groundnut, is one of the most important sources of vegetable oil and protein. To improve the nutritional quality of cereal-based traditional diets in Africa, the use of peanut flour as a protein supplement has often been suggested. Supplementation of sorghum flour with peanut flour produced acceptable food products such as *kisra* (Singh 1988) and *Tô* (T. Koleosho, U. Singh, and B. Singh, *unpublished data*).

Sosulski et al (1976) studied the functional properties of 10 grain legumes and reported considerable differences among different species. Functional characteristics of the defatted flours and concentrates are provided not only by the proteins of the seed but also by the complex carbohydrates: pectins and the hemicellulose components of the cells (Martinez 1979). According to Narayana and Narasingarao (1982), large differences existed in the functional properties of winged bean and soybean flours and in their raw and heat-processed samples. Functional properties of peanut protein isolates and protein concentrates have been the subject of several studies, reviewed by McWatters and Cherry (1982). However, information on the functional properties of sorghum flour as influenced by heating and fortification with peanut is needed in view of its increased utilization as a dietary component in combination with legumes, particularly peanut. Therefore, the objective of this study was to examine and compare the effects of heating on the functional properties of partially defatted peanut flour (PDPF), sorghum flour (SGF), and sorghum-peanut composite flour (SPCF).

MATERIALS AND METHODS

Peanut flour (Florunner US No. 1) was obtained from the Flavored Nuts Company, North Carolina Division, Seabrook Blanching Corp., Edenton, NC. Sorghum grains of cultivar Malisor 7 were received from the Agricultural Experiment Station, Texas A&M University, College Station, TX. Grain samples were cleaned and milled to pass a 0.5-mm screen. The peanut flour sample contained nearly 32% fat, which was reduced to about 19% by extraction with petroleum ether for 10 min using a Soxtek

apparatus (Tecator, Sweden). Thus, the peanut flour was partially defatted. Extracted samples were dried and then thoroughly mixed.

Preparation of Composite Flour

Sorghum-peanut composite flours, prepared by thoroughly mixing 200 g of sorghum flour with 50 g of peanut flour, were used for further analysis.

Heat Treatment

Two types of heat treatment, boiling and roasting, were used. Samples (50 g) were boiled in water (150 ml) for 30 min and dried in the oven at 50°C overnight. Dried material was milled to pass a 0.5-mm screen. PDPF, SGF, and SPCF were roasted at 165°C for 8 min in a cabinet drier (Proctor and Schwartz Inc., Horsham, PA).

Chemical Constituents

Moisture (method 44-15A), protein (46-11A), and fat (30-10) were determined in duplicate according to AACC approved methods (AACC 1983). The protein content was calculated using a conversion factor of 5.46 for peanut and 6.25 for sorghum.

Water and Oil Absorption

Water and oil absorptions were determined according to the method described by Beuchat (1977) with minor modifications. A 1-g sample was mixed with 10 ml of distilled water or oil for 30 sec using a vortex mixer (Fisher Scientific Co.). Samples were then allowed to stand at 30°C in a water bath for 30 min. The content was centrifuged at 3,015 × g for 20 min, and the volume of the supernatant was recorded. The density of peanut edible oil was determined to be 0.885 g/ml.

Gelation Capacity

The procedure of Coffmann and Garcia (1977) was suitably modified to determine gelation capacity. Sample suspensions containing 6–16% (w/v) flour in 0.5% increments were prepared in 10 ml of distilled water. The test tubes were heated for 1 hr in a boiling water bath, rapidly cooled under running cold tap water, and refrigerated for 3 hr at 40°C. The least gelation concentration was determined as that concentration at which the sample from an inverted test tube did not fall down or slip.

Emulsion Capacity

The method described by Beuchat (1977), with minor modifications, was employed for determination of emulsification capacity. The sample (1 g) was mixed with 50 ml of distilled water in a beaker for 2 min with continuous high-speed magnetic stirring. After complete dispersion, refined peanut oil was added continuously from a burette and stirred continuously until the emulsion broke, i.e., the mixture separated into two layers. Emulsification capacities (grams of oil per gram of protein) were determined in triplicate at 25°C.

Cooking Viscosity

The cooking viscosity (hot paste viscosity) of the samples were determined using a Brabender viscoamylograph (C.W. Brabender Instruments Inc., South Hackensack, NJ). Samples (50 g) were dispersed in 420 ml of distilled water in the macro bowl for analysis. The suspension was heated uniformly from 30 to 95°C (1.5°C/min increase) and held at 95°C for 15 min. The hot paste viscosity was recorded in Brabender units.

Nitrogen Solubility Index

The nitrogen solubility index (NSI) was determined in duplicate according to AACC approved method 46-23 (AACC 1983) with minor modifications. Samples (1 g) were weighed in 50-ml centrifuge tubes. Water (20 ml) was measured; a small portion was used to disperse the sample using the vortex mixer, and then the remainder of the water was added. The content was shaken on a mechanical shaker for 1 hr at room temperature and centrifuged at 7,720 × g for 15 min. The supernatant was collected,

and the residue was suspended and centrifuged twice with 10 ml of water. The supernatants were combined and analyzed for nitrogen by the standard Kjeldahl method. NSI values were expressed as the percent of nitrogen soluble in distilled water at room temperature (25°C).

Protein Dispersibility Index

The protein dispersibility index (PDI) was determined in duplicate according to AACC approved method 46-24 (AACC 1983). Different pH solutions, prepared using dilute hydrochloric acid and sodium hydroxide solutions, were used for determination of NSI and PDI.

Statistical Analysis

Data from this study were analyzed with an IBM 308 ID computer using the Statistical Analytical System (SAS) and Duncan's (1955) multiple range test, as described by the SAS Institute (1985).

RESULTS AND DISCUSSION

Processing affected the moisture, protein, and fat contents of PDPF, SGF, and SPCF (Table I). The protein content of PDPF was 52.6%, falling within the range of protein values for edible peanut flour (McWatters and Cherry 1982). The moisture content of PDPF was much lower than that of SGF. Boiling and roasting significantly decreased the protein content in both PDPF and SGF, but the effect was more pronounced in the roasting of PDPF (Table I). This might have been due to a loss in nitrogen at high temperature.

TABLE I
Protein, Fat, and Moisture Content
of Partially Defatted Peanut Flour (PDPF), Sorghum Flour (SGF),
and Sorghum-Peanut Composite Flour (SPCF)

Sample	Treatment	Moisture[a] (%)	Protein[a] (%)	Fat[a] (%)
PDPF	Raw	7.4 e	52.6 a	19.3 a
	Boiled	5.9 f	50.7 b	19.5 b
	Roasted	5.2 g	49.0 c	19.2 b
SGF	Raw	10.4 a	9.5 f	3.4 c
	Boiled	9.2 b	8.8 g	3.0 c
	Roasted	9.5 b	8.5 g	3.0 c
SPCF	Raw	8.9 c	18.0 d	6.0 d
	Boiled	8.3 d	17.7 d	6.1 d
	Roasted	9.0 c	16.9 e	5.8 d

[a]Means in the same column not followed by the same letter are significantly different from each other by Duncan's multiple range test at the $P < 0.05$ level.

TABLE II
Water Absorption, Oil Absorption, and Emulsion Capacity
of Partially Defatted Peanut Flour (PDPF), Sorghum Flour (SGF),
and Sorghum-Peanut Composite Flour (SPCF)

Sample	Treatment	Water[a] Absorption (g/g sample)	Oil[a] Absorption (g/g sample)	Emulsion Capacity[a] (g/g sample)	(g/g protein)
PDPF	Raw	1.18 f	0.89 d	24.5 a	46.6 a
	Boiled	1.70 c	1.41 c	18.0 b	35.5 b
	Roasted	2.53 a	1.65 b	23.9 a	48.7 a
SGF	Raw	1.40 d	1.63 b	1.5 e	15.8 e
	Boiled	1.92 b	2.24 a	1.0 f	11.4 g
	Roasted	1.73 c	2.05 a	1.2 f	14.1 f
SPCF	Raw	1.29 e	1.57 b	3.8 c	21.1 c
	Boiled	1.77 c	2.35 a	2.9 d	16.4 d
	Roasted	1.45 d	1.78 b	3.5 c	20.7 c

[a]Means in the same column not followed by the same letter are significantly different from each other by Duncan's multiple range test at the $P < 0.05$ level.

Processing affected the water absorption, oil absorption, and emulsion capacity of PDPF, SGF, and SPCF samples (Table II). Roasting increased the water absorption capacity of PDPF more than twofold. In the case of SGF, boiling significantly increased both water and oil absorption, but the effect was more pronounced for oil absorption. Also the oil absorption of SPCF increased remarkably due to boiling. Boiling of mung bean flour (del Rosario and Flores 1981) and autoclaving of winged bean (Narayana and Narasingarao 1982) also considerably increased water and oil absorption. Water absorption by PDPF in the present investigation was lower than that of soybean flour and sunflower flour (Sosulski and Fleming 1977). Water absorption by soybean flour ranged between 130 and 227.3%, and oil absorption was between 84.4 and 133.0% (Lin et al 1974).

Emulsion capacities were affected by sample and heating processes (Table II). Emulsion capacities varied from 24.5 g/g for PDPF to 1.5 g/g for SGF and 3.8 g/g for SPCF. Boiling and roasting slightly decreased the emulsion capacity of SGF; the emulsion capacity of PDPF was significantly reduced by boiling but not by roasting. Lin et al (1974) reported that the emulsion capacities of wheat, soy, and sunflower flours and of protein concentrates and isolates from soy and sunflower flours were in the range of 10.1 to 25.6%, with the exception of sunflower flour (95.1%) oil emulsified. Sathe et al (1982) reported that emulsion capacities of flour and protein concentrates of winged bean were 71.1 and 222.2 g/g, respectively. The emulsion capacity of the sorghum flour in the present study was considerably lower

than that of the wheat flour reported by Lin et al (1974). The observed emulsion capacity of peanut flour was lower than the literature values reported for several oilseed and dry bean flours (Cante et al 1979, Kinsella 1979).

Emulsion stability can be greatly increased when highly cohesive films are formed by the absorption of rigid globular protein molecules that are more resistant to mechanical deformation, e.g., lysozyme (Graham and Phillips 1980). The high emulsion stability of protein concentrates may be due to the major proteins of winged beans being globular (Gillespie and Blagrove 1978). McWatters and Cherry (1982) reviewed the various factors that influence the emulsion capacity and indicated that pH and ionic concentration were the major factors that affected the emulsion capacity of the peanut flour.

The gelation capacity and cooking viscosity (hot-paste viscosity) of PDPF, SGF, and SPCF are summarized in Table III. Gelation capacities for raw, boiled, and roasted PDPF were 10.0, 12.5, and 10.5%, respectively, showing a small variation. The boiled PDPF required a significantly higher concentration (12.5%) for gel formation. These values were comparable to those of Great Northern bean protein concentrate (Sathe and Salunkhe 1981) and mung bean protein isolate (Coffmann and Garcia 1977). On the other hand, SGF concentrations for gelation were significantly lower than those of PDPF. Sorghum flour contained starch, which induced gelation due to starch-starch and/or starch-protein interactions. SPCF required a higher flour concentration than SGF for gelation because the starch content decreased due to fortification with peanut flour. The hot-paste viscosity was not recorded for PDPF, whereas for SGF and SPCF, the hot paste viscosity values were 630 and 405 BU, respectively. These values were reduced to 405 and 285, respectively, as a result of boiling. Since the hot paste viscosity is primarily a function of the starch granules, which swell due to heating, PDPF did not produce any peak because of its very low starch content.

The NSI and PDI decreased after processing (Table III). Wet-heating (boiling) reduced the NSI and PDI of PDPF more than did dry-heat treatment (roasting). This observation partly supported the finding of Cherry et al (1975), who reported that the heating of full-fat peanut seed in water at 100–120°C decreased protein solubility due to the conversion of soluble proteins to insoluble forms.

Grain legume proteins show different solubility patterns at different pH levels of the extracting solvent. Protein solubility of peanut flour was greatly affected by pH and ionic strength (Beuchat et al 1975, McWatters and Cherry 1982). The NSIs of PDPF and SPCF at different pH levels are illustrated in Figures 1 and 2, respectively. Interactions due to heat treatments were noticed, as the NSI values of raw, boiled, and roasted PDPF showed different patterns. The NSI value was lowest at pH 4.5

TABLE III
Gelation Capacity, Viscosity, Nitrogen Solubility Index (NSI), and Protein Dispersibility Index (PDI) of Partially Defatted Peanut Flout (PDPF), Sorghum Flour (SGF), and Sorghum-Peanut Composite Flour (SPCF)

Sample	Treatment	Gelation Capacity[a] (% flour)	Viscosity[a] (peak height in BU)	NSI[a] (%)	PDI[a] (%)
PDPF	Raw	10.0 b	...	43.6 a	30.9 a
	Boiled	12.5 a	...	27.5 c	21.7 c
	Roasted	10.5 b	...	38.7 b	28.0 b
SGF	Raw	5.5 f	630 a	16.1 e	9.8 f
	Boiled	8.0 d	438 c	10.7 g	7.3 g
	Roasted	7.5 d	525 b	14.6 f	9.5 f
SPCF	Raw	7.0 e	405 d	22.6 d	13.5 d
	Boiled	9.5 c	285 f	14.4 f	11.6 e
	Roasted	9.3 c	302 e	20.0 d	12.0 e

[a] Means in the same column not followed by the same letter are significantly different from each other by Duncan's multiple range test at the $P < 0.05$ level.
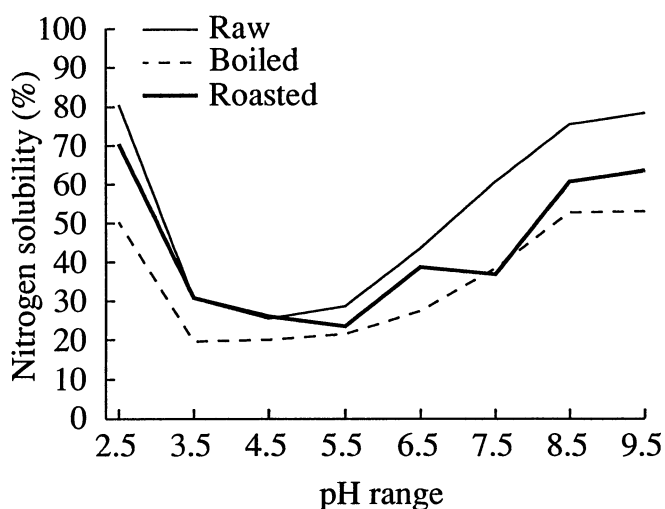

Fig. 1. Nitrogen solubility of raw, boiled, and roasted partially defatted peanut flour at different pH levels.
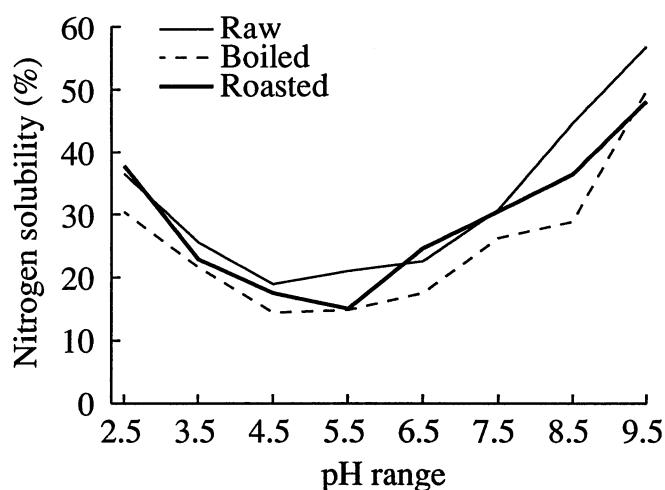

Fig. 2. Nitrogen solubility of raw, boiled, and roasted partially defatted sorghum-peanut composite flour at different pH levels.

in raw PDPF, whereas it was lowest at pH 3.5 and 5.5 in boiled and roasted samples, respectively (Fig. 1). The NSI patterns of raw and heat-processed samples of SPCF differed from those of PDPF flour (Fig. 2). The lowest NSI value was obtained at pH 4.5 in both raw and boiled SPCF, and a faster increase in NSI values was noticed as the solvent pH increased. This might have been due to increased solubility of the sorghum glutelin fraction at higher pH. However, heat treatment greatly reduced the NSI values at all pH levels in both PDPF and SPCF.

CONCLUSION

Peanut protein has great potential as a functional agent in fabricated foods and supplements in the diets of undernourished people, particularly in the developing countries. The raw and processed composite flours of sorghum and peanut exhibited interesting functional properties. The emulsion capacity and the NSI of sorghum flour were considerably improved as a result of fortification. Further studies are required to understand the reactions of peanut proteins with specific constituents of sorghum, such as starch. This information is needed to design protein-enriched sorghum foods for sorghum-growing regions of the world.

LITERATURE CITED

AMERICAN ASSOCIATION OF CEREAL CHEMISTS. 1983. Approved Methods of the AACC. 1983. Method 30-11, approved April 1961, revised October 1975 and October 1981; Method 44-15A, approved October 1975, revised October 1981; Method 46-11A, approved October 1976, revised October 1982 and September 1985; Methods 46-23 and 46-24, approved April 1965, revised October 1975, reviewed October 1982. The Association: St. Paul, MN.

BEUCHAT, L. R. 1977. Functional and electrophoretic characteristics of succinylated peanut flour proteins. J. Agric. Food Chem. 25:258.

BEUCHAT, L. R., CHERRY, J. F., and QUINN, M. R. 1975. Physicochemical properties of peanut flour as affected by proteolysis. J. Agric. Food Chem. 23:617.

CANTE, C. J., FRANZEN, R. W., and SALEEB, F. Z. 1979. Proteins as emulsifiers: Methods for assessing the role. J. Am. Oil Chem. Soc. 56:71.

CHERRY, J. P., McWATTERS, K. H., and HOLMES, M. R. 1975. Effect of moist heat on solubility and structural components of peanut proteins. J. Food Sci. 40:1199.

COFFMANN, C. W., and GARCIA, V. V. 1977. Functional properties and amino acid content of a protein isolate from mung bean flour. J. Food Technol. 12:473.

del ROSARIO, R. R., and FLORES, D. M. 1981. Functional properties of four types of mung bean flour. J. Sci. Food Agric. 32:175.

DUNCAN, B. D. 1955. Multiple range and multiple F tests. Biometrics 11:1.

GILLESPIE, J. M., and BLAGROVE, R. J. 1978. Isolation and composition of the seed globulins of winged bean. Aust. J. Plant Physiol. 5:357.

GRAHAM, D. E., and PHILLIPS, M. C. 1980. The conformation of proteins at the air-water interface and their role in stabilizing foam. Page 237 in: Foams. R. J. Akers, ed. Academic Press: London.

KINSELLA, J. E. 1979. Functional properties of soy proteins. J. Am. Oil Chem. Soc. 56:242.

LIN, M. J. Y., HUMBERT, E. S., and SOSULSKI, F. 1974. Certain functional properties of sunflower meal products. J. Food Sci. 39:368.

MARTINEZ, W. H. 1979. Functionality of vegetable proteins other than soybeans. J. Am. Oil Chem. Soc. 56:280.

McWATTERS, K. H., and CHERRY, J. P. 1982. Potential food uses of peanut seed proteins. Pages 689-736 in: Peanut Science and Technology. H. E. Pattee and C. T. Young, eds. American Peanut Research and Education Society, Yoakum, TX.

NARAYANA, K., and NARASINGARAO, M. S. 1982. Functional properties of raw and heat processed winged bean flour. J. Food Sci. 47:1534.

SAS INSTITUTE. 1985. SAS User's Guide: Statistics, Version 5 edition. The Institute: Cary, NC.

SATHE, S. K., DESHPANDE, S. S., and SALUNKHE, D. K. 1982. Functional properties of winged bean proteins. J. Food Sci. 47:503.

SATHE, S. K., and SALUNKHE, D. K. 1981. Functional properties of the great northern bean (Phasiolus vulgaris) proteins: Emulsion, foaming, viscosity, and gelation properties. J. Food Sci. 46:71.

SINGH, B. 1988. An interdisciplinary approach to optimum food utility of the peanut in SAT Africa. Page 240 in: Annual Report Peanut Collaborative Research Support Program, University of Georgia, Georgia Experiment Station, Griffin.

SOSULSKI, F. W., and FLEMING, S. E. 1977. Chemical, functional and nutritional properties of sunflower protein products. J. Am. Oil Chem. Soc. 54:100.

SOSULSKI, F. W., GARRATT, M. D., and SLINKARD, A. E. 1976. Functional properties of ten legume flours. Can. Inst. Food Sci. Technol. J. 9:66.