Functional Properties of Dehulled Sesame (*Sesamum indicum* L.) Seed Flour

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Certain functional properties of sesame seed flour were obtained after oil extraction from dehulled seed meal was investigated. The protein content in the flour was 69.7% and the least gelation concentration was 6.0%. Water and oil absorption capacities at room temperature (31 ± 2°C) were 2.3 g H_2O/g sample and 3.0 g oil/g sample, respectively. The values were higher at 100°C. The emulsification capacity, which was more stable at alkaline conditions, ranged from 25.0 mL oil/g sample at pH 4 to 66.0 mL oil/g sample at pH 10. The foaming capacity was more stable at pH 4 but lower (205.0%). The highest foaming capacity (315.0%) was at pH 2 whereas at pH 10 it was 310.0%. Protein solubility, which was least at pH 4, ranged from 7.9% at pH 2 to 14.2% at pH 10. The viscosity of the flour dispersion ranged from 2.5 cps at 1% concentration to 7.0 cps at 10% concentration. The findings show that sesame flour could impart desirable characteristics when incorporated into products such as ice cream, frozen dessert, sausages, baked food and confections.

KEY WORDS: Emulsification, foamability, gelation, oil and water absorption, sesame seed flour, solubility, whippability.

In many parts of the world where sesame is being cultivated, its most important use is for the production of oil, which is highly valued for its flavor. The meal obtained after oil extraction is usually fed to animals as a source of protein. In areas where the meal is eaten by humans, dehulling is necessary because the hull contains large amounts of undesirable oxalic acid and undigestible fiber, which imparts dark color to the meal (1). The meal or cake resulting from the production of oil is a high-protein concentrate with protein content varying from 400–500 g/kg dry matter, depending on the method of oil extraction (2). Unlike many oilseeds, the defatted flour or protein extract prepared from dehulled seeds does not contain undesirable pigment (3). Sesame seed is poor in lysine (2.7%), but its protein is rich in methionine (3.2%), which is often the limiting amino acid in legume-based tropical diets (3). Because of its unique properties, sesame seed protein can be used for supplementing peanut, soybean and other vegetable proteins that lack sufficient methionine to increase their nutritive qualities. However, to be successfully exploited for use as a food ingredient, the protein must possess satisfactory functional properties such as gelation, emulsion stability, viscosity, foamability and aqueous solubility. Therefore, the objective of this study was to investigate the functional properties of food-grade flour from sesame seed and to predict its utilization in food formulation.

MATERIALS AND METHODS

Sesame seeds were purchased from three different markets in Makurdi, the capital of Benue State, Nigeria, West Africa. Seeds were thoroughly mixed to obtain a composite sample that was then processed into flour.

Seed dehulling. Seeds were dehulled by the wet method described by Toma *et al.*, (1). Seeds were soaked in tap water for 18 h and washed, and while being washed, they were rubbed by hand to decorticate them. Seeds, together with hulls were sun-dried for about 42 h at ambient temperature (31 ± 2°C), and hulls were removed by winnowing and screening.

Flour preparation. Dehulled seeds were flaked and extracted with food-grade *n*-hexane for 8 h in a Soxhlet apparatus. The meal was dried and milled to pass through a 75-mesh screen.

Proximate analysis. Moisture, fat, protein and ash were determined according to AOAC (4). Carbohydrate was calculated by difference (5).

Gelation capacity. The method of Coffmann and Garica (6) was used.

Emulsification capacity (EC) and stability (ES). The method of Sathe and Salunkhe (7) was used. A sample (2 g) was blended at high speed in a Waring blender with 100 mL of distilled water for 30 s. Soy oil was added in 5-mL portions during blending at pH 2 to 10. The drop in consistency judged by a decreased resistance to blending (subjectively) was considered to be the point of discontinuation of oil addition. The quantity of oil added up to this point was noted and EC was expressed as the quantity (mL) of oil emulsified by 1 g of product.

The emulsion was allowed to stand in a 100-mL graduated cylinder and volumes of water separated at 10-min time intervals were noted to determine emulsion stability (ES). All experiments were conducted at room temperature (31 ± 2°C).

Water and oil capacities. Water absorption capacity was determined by the method of Beuchat (8) and expressed as grams of water absorbed (retained) per gram of sample. Oil absorption capacity was determined by the method of Beuchat (8) and expressed as grams of oil absorbed per gram of sample.

Foam capacity (FC) and stability (FS). The method of Lin *et al.* (9) was used. Foam capacity (FC) was expressed as percentage volume increase and calculated as shown below:

$$FC = \frac{\text{vol after whipping} - \text{vol before whipping}}{\text{vol before whipping}} \times 100 \quad [1]$$

Foam stability was determined by measuring the foam height at several intervals up to 180 min. Both the foam capacity and stability were determined over a pH range of 2 to 10 at room temperature (31 ± 2°C).

Protein solubility. The method of Sathe *et al.* (10) was used.

Viscosity determination. The method of Beuchat (8) was used. Each sample was prepared at 1 to 10% concentrations (w/v) and viscosity was measured at room temperature (31 ± 2°C) with a Brookfield Synchro-Electric Viscometer (Model LV8), Chingford, London.

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TABLE 1

Proximate Composition of Sesame Seed and Flour Obtained from Dehulled Seeds

Parameters (%)	Samples		
	Whole seed	Dehulled seed	Flour (from extracted dehulled seed)
Moisture	5.0 ± 0.1	5.3 ± 0.1	6.0 ± 0.1
Fat	51.5 ± 0.2	55.0 ± 0.2	0.5 ± 0.0
Protein	20.0 ± 0.2	24.3 ± 0.2	69.7 ± 0.3
Fiber	6.0 ± 0.2	2.0 ± 0.0	0.3 ± 0.0
Ash	5.0 ± 0.2	3.0 ± 0.0	6.0 ± 0.2
Carbohydrate	12.5 ± 0.2	10.4 ± 0.3	17.5 ± 0.3

RESULTS AND DISCUSSION

Proximate composition. Proximate compositions of the whole sesame seed, dehulled seed and extracted flour obtained from dehulled seed are shown in Table 1.

Since sesame is an oilseed, extraction of oil from the dehulled seed meal led to increases in other constituents in the flour. The major increase was in protein content which ranged from 24.3% in the meal from dehulled seeds to 69.7% in the extracted flour. This shows that sesame flour is a good source of protein.

Gelation properties. The gelation properties of the sesame flour are shown in Table 2.

The least gelation concentration of the flour was 6% (w/v). Below this concentration, no gel formed. This value is comparable to that reported by Ihekoronye (11) for defatted peanut flour but lower than those reported by others (7,12,13) for Great Northern bean flour (10%), brown bean flour (18%) and winged bean flour (14%). The gel strength increased as the concentration of solid in the dispersion increased. This result suggests that gel strength would make sesame protein useful in food systems such as sauces and puddings that require thickening and gelling.

The effect of heating temperature and time on gelling property of the flour is shown in Table 3.

Using the least gelation concentration (6%), we observed that the flour only formed gel on heating to 90°C for 20 min followed by rapid cooling. Below this temperature, no gel formed. The strength of the gel increased with heating time above 30 min. This might be due to a decrease in moisture with heating time.

Emulsion capacity (EC) and stability (ES). Emulsion capacity and stability of sesame flour are shown in Table 4. Emulsion capacity and stability were affected by pH within a range of 2–10. Emulsions formed at pH 4, which is likely the isoelectric point of the protein. Earlier, Arthur and Volkert (14) and Rivas *et al.* (15) have precipitated extracted sesame protein at pH 4 (isoelectric point). Above or below pH 4, the emulsion capacity increased. A maximum capacity of 66.0 mL oil/g flour occurred at pH 10. The stability of the emulsion was also highest at pH 10 and the lowest at pH 4. Similar observations were reported by Franzen and Kinsella (16) and by Ihekoronye (11) for soy flour and peanut flour, respectively. The emulsion capacity and stability observed in this study were higher than that of peanut flour (11).

Water absorption capacity. The ability of protein to bind water is an important function in foods such as processed cheese, doughs and sausages. The results of water and oil absorption capacities of sesame flour are shown in Table 5. The flour exhibited a high water absorption capacity both at atmospheric conditions and when treated with boiling water. At atmospheric conditions, the water absorption capacity of the flour was 2.3 g H_2O/g sample. This value was comparable to 2.4 g H_2O/g sample reported by Sosulski and Fleming (17) and Abbey and Ibeh (18) for soy flour and cowpea flour, respectively, but higher than the 1.1 and 0.8 g H_2O/g sample reported by Lin *et al.* (9) and by del Rasario and Flores (19) for sunflower flour and mung bean flour, respectively. Treatment of the flour with boiling water resulted in an increase in water absorption capacity from 2.3 to 2.7 g H_2O/g sample. This increase could be due to the dissociation of the protein on heating and denaturation that could unmask the nonpolar residues from the interior of the protein molecule. Carbohydrate in the flour may also contribute to the increased water absorption capacity. Similar increases in water absorption capacity on heating were reported by del Rasario and Flores (19) and by Abbey and Ibeh (18) for mung bean flour and cowpea flour, respectively.

TABLE 2

Gelation Properties of Sesame Flour

Sample concentration (%)	Gelation strength
2	No gel
4	No gel
6	Very weak
8	Weak
10	Strong
12	Strong

TABLE 3

Effect of Heating Temperature and Time on Gel Formation at the Least Gelation Concentration of 6%

Heating time (min)	Temperature (°C)		
	70	80	90
10	No gel	No gel	No gel
20	No gel	No gel	Very weak
30	No gel	No gel	Very weak
40	No gel	No gel	Weak
50	No gel	No gel	Weak
60	No gel	No gel	Weak

TABLE 4

Emulsion Capacity and Stability of Sesame Flour

Emulsion pH	Emulsion capacity (mL oil/g sample)	Emulsion stability (mL H_2O separated after time (min))									
		10	20	30	40	50	60	70	80	90	100
2	45.0 ± 0.3	7.7	7.7	8.6	8.6	10.7	10.7	11.6	11.7	12.7	12.7
4	25.0 ± 0.2	10.3	10.3	11.2	12.3	12.3	12.3	13.7	13.8	14.3	14.3
6	53.3 ± 0.3	9.2	9.2	10.3	10.3	11.3	11.3	12.7	12.7	13.6	13.6
7	55.7 ± 0.2	6.7	8.3	8.3	9.3	9.3	10.7	10.7	11.3	11.3	11.3
8	61.0 ± 0.2	5.7	5.7	6.7	6.7	6.7	7.0	7.8	7.8	8.7	8.7
10	66.0 ± 0.2	1.3	1.3	1.6	1.6	1.8	1.8	2.3	2.3	4.0	4.0

TABLE 5

Water and Oil Absorption Capacities of Sesame Flour

Parameters	Treatment temperatures	
	Ambient Temp. (31 ± 2°C)	Boiling Temp. (100°C)
Water absorption capacity (g H_2O/g sample)	2.3 ± 0.0	2.7 ± 0.0
Oil absorption capacity (g oil/g sample)	3.0 ± 0.0	6.2 ± 0.2

Oil absorption capacity. At atmospheric temperatures, the oil absorption capacity of sesame flour was 3.0 g oil/g sample (Table 5). This result was comparable to that reported by Sathe and Salunkhe (7) for Great Northern bean flour but higher than those reported by del Rasario and Flores (19) and Okozie and Bello (13) for mung bean flour and winged bean flour, respectively. Treatment of the flour with oil at 100°C resulted in an increase in oil absorption capacity from 3.0 to 6.2 g oil/g sample. A similar increase in the oil absorption capacity was reported by Abbey and Ibeh (18) for cowpea flour. These results show that sesame flour might be suitable in food products such as cakes, doughnuts, confections, soups, beverages, meat replacers and extenders.

Foam capacity (FC) and stability (FS). Data in Table 6 show the foam capacity and stability of sesame flour. The foamability varied over the pH range of 1–10. It was lowest (205%) at pH 4, which appears to be the isoelectric region of the protein (14,15). At pH above or below 4, the foam capacity increased with the highest (315%) being at pH 2. At pH 10, the value was 310%.

Maximum stability of the foam occurred at pH 4. Acid pH favored foam stability more than alkaline pH. The high stability of foam in the acid pH range may be due to the formation of stable molecular layers at the air-water interface that impart texture, stability and elasticity to the foams (20). Similar dependence of foaming characteristics on pH were reported by Canella *et al.* (20) and by Abbey and Ibeh (18) for succinylated and acetylated sunflower flours and cowpea flour, respectively. With high foaming capacity and stability, sesame flour might be useful for products such as ice cream, frozen dessert and toppings.

Protein solubility. Figure 1 shows the protein solubility of sesame flour within a pH range of 2–10. The least protein solubility (3.2%) occurred at pH 4. At pH above or below 4, the solubility increased, averaging 7.9% at pH 2 and 14.2% at pH 10. Similar variations in protein solubility with pH were reported by Sosulski *et al.* (21), McWatters and Holmes (22), Dench (23) and Abbey and Ibeh (18) for sunflower flour, peanut flour, winged bean flour and cowpea flour, respectively. The protein solubility observed in this study was lower than 16.1% reported by Lin *et al.* (9) for sunflower flour.

TABLE 6

Foam Capacity and Stability of Sesame Flour

Dispersion pH	Volume after whipping (mL)	Volume increase (%)	Foam stability [volume (mL) at room temperature (31 ± 2°C) after time (min)]						
			10	30	60	90	120	150	180
2	415.0 ± 0.2	315	415	413	410	410	408	406	406
4	305.0 ± 0.2	205	305	303	303	302	302	300	300
6	366.0 ± 0.3	266	365	363	360	358	356	355	355
7	327.0 ± 0.2	227	327	324	321	319	317	315	315
8	330.0 ± 0.3	230	330	327	323	320	318	316	316
10	410.0 ± 0.2	310	410	408	405	400	397	395	394

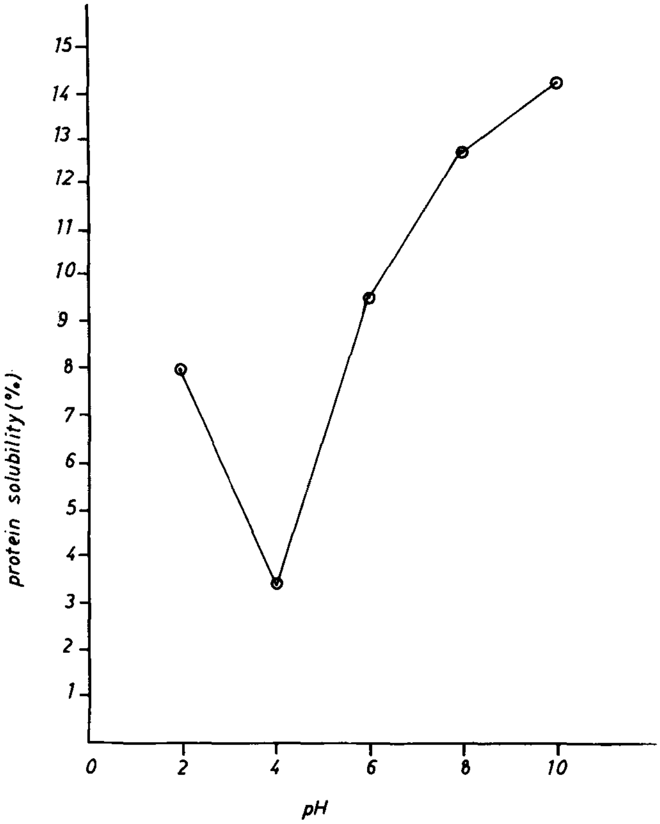

FIG. 1. Effect of pH on the solubility of sesame flour protein.

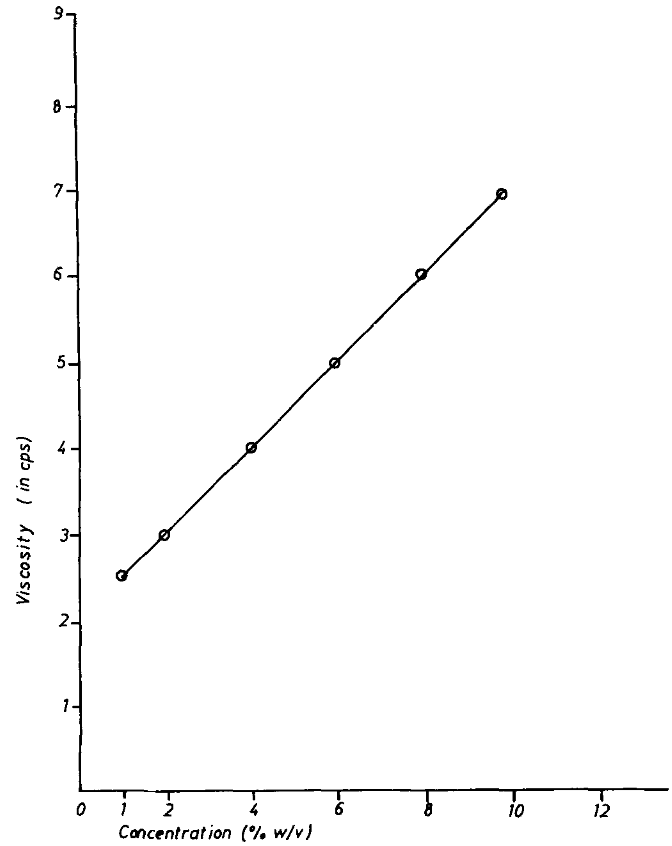

FIG. 2. Viscosity measurement of flour dispersion.

Viscosity. Viscosities of the flour dispersions are shown in Figure 2. The apparent viscosity of the flour dispersion at various solid concentrations (1–10%) in distilled water at neutral pH (pH 7.0) increased with increasing concentration. This increase was from 2.5 cps at 1% to 7.0 cps at 10% concentration (Fig. 2). The viscosities observed in this study were higher than reported for defatted peanut flour (11).

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