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Traditional Processing Treatments as a Promising Approach To Enhance the Functional Properties of Rapeseed (*Brassica campestris* Var. *toria*) and Sesame Seed (*Sesamum indicum*) Meals

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Different processing treatments were applied to rapeseed and sesame seed meals, and the functional properties of these products were assessed. All treatments except puffing for both meals and pressure cooking in sesame meal increased water absorption capacity (WAC). Fat absorption capacity (FAC) of rapeseed meals was enhanced significantly by all treatments. The full-fat meals of both sources showed maximum protein solubility when fermented and minimum protein solubility when pressure-cooked. Germinated and microwave-cooked meals enhanced foaming properties of rapeseed meals. Heat treatments, except microwave cooking, considerably reduced emulsifying properties of both meals. Fermentation and germination increased the specific viscosity of rapeseed meals, whereas processed sesame meals showed lower viscosity than dry sesame meals.

Keywords: *Functional properties; rapeseed; sesame seed; traditional processing*

INTRODUCTION

Everybody expects food to be palatable, nutritious, and wholesome. These attributes are affected by the composition of the food as well as by the physical and chemical properties and functionality of the constituents. They can be controlled by the recipe of the formulation, the conditions of storage and processing, and the enzymatic or chemical modifications of the components, mainly lipids, proteins, carbohydrates, and vitamins (Sikorski, 1996).

Rapeseed and sesame seeds are important oilseed crops, and the meals left after the extraction of oil are rich in proteins. These meals are mainly utilized for livestock feed. Recently, attention has been directed toward exploring the utilization of oilseed meal proteins for food use on the basis of their functional properties. However, to be utilized effectively, these proteins should not only have satisfactory intrinsic properties, that is, nutritional value and acceptable flavor, color, and texture, but also possess additional critical functional properties that make them compatible with and enhancing to the food to which they are added. These criteria are often overlooked in the discussions of plant protein sources when only quantity of protein and its biological value are normally considered.

The utility of rapeseed in food products is handicapped due to the presence of some antinutritional factors such as glucosinolates, phenols, and phytic acid. A variety of processes involving chemical, enzymatic, microbiological, or physical treatments alone or in combination have been reported for detoxification of rapeseed (Zhou et al., 1990; Mahajan and Dua, 1994a,b; Dua et al., 1996) and to improve functional properties of protein products. However, proteins do not exist in the native form after these treatments. Also, there is the added cost of processing. Keeping in mind the economic criterion, the traditional processing treatments are less expensive, simple, and easy to carry out. The processing methods selected in the present study, namely, roasting, puffing, pressure and microwave cooking, germination, and fermentation, which can be undertaken even on a kitchen shelf, reduce the undesirable substances and improve the functional properties. The ultimate success of utilizing them in food formulations depends largely upon the functional attributes.

MATERIALS AND METHODS

Pure-line rapeseed (*Brassica campestris* var. *toria*) seeds were obtained from Punjab Agricultural University, Ludhiana, India. Sesame seeds were obtained from District Development Authority, Una, Himachal Pradesh, India.

All chemicals used were of an analytical grade.

Quality seeds were selected and subjected to the following treatments.

Roasting. Seeds (25 g) were roasted in 500 g of acid-washed sand at 240 °C for 2 min and then passed through a sieve to remove sand particles.

Puffing. Seeds (25 g) were soaked in 200 mL of water (26 °C) for 3 h. After the water had been drained, seeds were puffed over hot sand (500 g) at 250 °C for 3 min and then passed through a sieve.

Pressure Cooking. Seeds (100 g) were pressure-cooked with sufficient water (1900 mL) at 15 lb (1.1 kg/cm^2) and 121 °C temperature for 7 min. After cooking, the excess water was drained off, and the seeds were sun-dried.

Microwave Cooking. Seeds (25 g) after soaking in water for 3 h were exposed to microwave cooking (microwave frequency = 2450 MHz; microwave output power = 600 W) for 10 s. Temperature of the microwave-cooked seeds was found to be 33 °C. The seeds were finally sun-dried.

Germination. After sterilization with 0.1% mercuric chloride, dry seeds were soaked in water for 8 h and allowed to germinate in Petri plates for 72 h at room temperature (30 °C). These germinated seeds were then sun-dried.

Fermentation. Seeds (50 g) were soaked in distilled water (500 mL) at 26 °C for 8 h and ground into a homogeneous paste in a pestle. The paste was allowed to ferment aerobically under natural conditions for 16 h at room temperature (30 °C). Fermented meal (pH 6.1) was sun-dried (Padmashree et al., 1987).

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Table 1. WAC (Grams per Gram of Meal) of Processed Rapeseed Meal and Sesame Seed Meal[a]

	rapeseed meal		sesame seed meal	
processing treatment	fatted	defatted	fatted	defatted
dry seed (control)	2.12 ± 0.09	2.57 ± 0.09	2.49 ± 0.19	3.87 ± 0.19
roasting	3.31 ± 0.08	4.25 ± 0.05	4.23 ± 0.39	4.41 ± 0.27
puffing	1.97 ± 0.08	2.38 ± 0.10	1.02 ± 0.02	1.34 ± 0.27
pressure cooking	2.53 ± 0.09	2.99 ± 0.13	0.92 ± 0.12	1.82 ± 0.51
germination	3.86 ± 0.05	4.33 ± 0.05	5.80 ± 0.23	6.60 ± 0.31
fermentation	2.42 ± 0.08	3.73 ± 0.09	5.86 ± 0.10	5.97 ± 0.14
microwave cooking	2.81 ± 0.06	3.31 ± 0.80	3.30 ± 0.02	4.45 ± 0.29

[a] All values are significant at $p < 0.05$. Means ± SD.

All seeds after different processing treatments were ground to a fine powder. Each type of meal was divided into two parts; one was kept as full-fat meal, and the other was defatted. For defatting, 50 g of seeds was extracted with 100 mL of petroleum ether at room temperature (30 °C) for 1 h. The supernatant was decanted, and the seeds were again treated with petroleum ether three times. Finally, the meal was dried at room temperature. The residual lipid content of the defatted meal was 0.6%.

Functional Properties. The following properties were evaluated for each of the meals.

Water Absorption Capacity (WAC) and Fat Absorption Capacity (FAC). WAC and FAC were determined according to the methods of Beuchat et al. (1975) and Sosulski et al. (1976), respectively. The values are expressed as grams of water absorbed per gram of meal for WAC and grams of oil absorbed per gram of meal for FAC.

Protein Solubility. Protein solubility was determined by placing 100 mg of each meal in 5 mL of distilled water. The mixtures were shaken for 1 h using a metabolic shaker to extract soluble proteins and then centrifuged at 3000 rpm for 15 min at room temperature (30 °C). Supernatant was used to estimate the protein content according to the method of Lowry et al. (1951), using bovine serum albumin as the standard.

Foaming Properties. Five grams of meal was dispersed in 20 mL of distilled water and homogenized using a metabolic shaker for 30 min. It was followed by centrifugation of the homogenate at 3000 rpm for 15 min at 30 °C. Supernatant so obtained (known volume) was whipped for 5 min on a stirrer at 1200 rpm and poured into a 100 mL measuring cylinder, and its volume was immediately noted. Foam capacity (FC) was expressed as percent increase in the volume of meal extract (supernatant) according to the formula of Lawhon et al. (1972):

$$\mathrm{FC} = \frac{\text{vol after whipping} - \text{vol before whipping}}{\text{vol before whipping}} \times 100$$

The foam volume was recorded at different time intervals after whipping to determine foam stability (FS) according to the method of Ahmed and Schmidt (1979):

$$\mathrm{FS} = \frac{\text{foam vol after time } t}{\text{initial foam vol}} \times 100$$

Emulsification Properties. Emulsification properties were studied according to the procedure of Yasumatsu et al. (1972).

Emulsifying Activity (EA). To 1.5 g of meal was added 15 mL of distilled water, and the mixture was homogenized on a stirrer (Remi, Multipurpose stirrer RQ/123) for 2 min. These dispersions were then shaken over a metabolic shaker (horizontal type) for 0.5 h and centrifuged at 4000 rpm for 15 min at 30 °C. To 5 mL of the supernatant was added 5 mL of groundnut oil, and the mixture was again homogenized for 5 min at 3000 rpm. EA was calcualted as

$$\mathrm{EA} = \frac{\text{height of the emulsified layer}}{\text{height of total content in the tube}} \times 100$$

Emulsion Stability (ES). The same procedure for emulsifying activity, except for heating (80 °C for 30 min in a water bath) and cooling (under running tap water for 15 min) the emulsion before centrifugation, was used. Emulsion stability was calculated as

$$\mathrm{ES} = \frac{\text{height of the emulsified layer}}{\text{height of total content in the tube}} \times 100$$

Viscosity. Five grams of each meal was dispersed in 20 mL of water, and the extract was centrifuged at 4000 rpm for 15 min at 30 °C. Fifteen milliliters of the supernatant was placed in an Ostwald viscometer, and its time of flow was noted with a stopwatch accurate to 0.1 s. Viscosity of the solution was calculated as given by Mahajan and Dua (1994a,b).

RESULTS AND DISCUSSION

WAC. Dry full-fat and defatted rapeseed meals had WAC values of 2.12 and 2.57 g/g of meal, respectively; the corresponding values for sesame seed meals were 2.49 and 3.87 g/g of meal (Table 1). All of the treatments except puffing increased the WAC in both types of meals, and increases were significant ($p < 0.05$) relative to the control. Germination enhanced the WAC the greatest. This could be attributed to the changes in the quality of the proteins upon germination (del Rosario and Flores, 1981).

The enhanced WAC of heat-processed seeds may be due to the denaturation of proteins that facilitates additional binding sites available for water binding (Kinsella, 1982), or it may be due to the gelation of carbohydrates and swelling of crude fiber due to heat treatment as reported in winged bean (Narayana and Narasinga Rao, 1982).

Fermentation also improved the WAC of rapeseed and sesame seed meals. Similar findings have been observed by Beuchat et al. (1975), who reported that fungal fermentation increased water retention capacity of defatted peanut flour. The WAC of defatted meals was better than that of full-fat meals of both seeds. Defatting results in exposure of water binding sites on side-chain groups of proteins previously blocked in a lipophilic environment and, therefore, increases the WAC of defatted meals.

WAC is considered a critical function of proteins in viscous foods such as soups, gravies, doughs, and baked products (Sosulski et al., 1976). Hence, increased WAC of rapeseed and sesame meals observed in the present study due to some processing treatments can be made use of in these products.

FAC. All processing treatments significantly ($p < 0.05$) increased the FAC of full-fat and defatted seed meals except roasted and pressure-cooked sesame seed

Table 2. FAC (Grams per Gram of Meal) of Processed Rapeseed Meal and Sesame Seed Meal[a]

	rapeseed meal		sesame seed meal	
processing treatment	fatted	defatted	fatted	defatted
dry seed (control)	1.04 ± 0.05	1.81 ± 0.14	1.89 ± 0.12	2.52 ± 0.18
roasting	1.67 ± 0.03	2.06 ± 0.11	1.08 ± 0.01	2.06 ± 0.06
puffing	1.37 ± 0.04	2.12 ± 0.04	2.02 ± 0.05	2.80 ± 0.09
pressure cooking	1.15 ± 0.05	3.12 ± 0.11	1.37 ± 0.09	3.40 ± 0.02
germination	2.17 ± 0.04	3.12 ± 0.07	2.87 ± 0.02	3.88 ± 0.02
fermentation	1.28 ± 0.02	2.31 ± 0.06	2.16 ± 0.13	2.22 ± 0.11
microwave cooking	2.07 ± 0.07	4.52 ± 0.07	2.16 ± 0.80	3.57 ± 0.07

[a] All values are significant $p < 0.05$. Means ± SD.

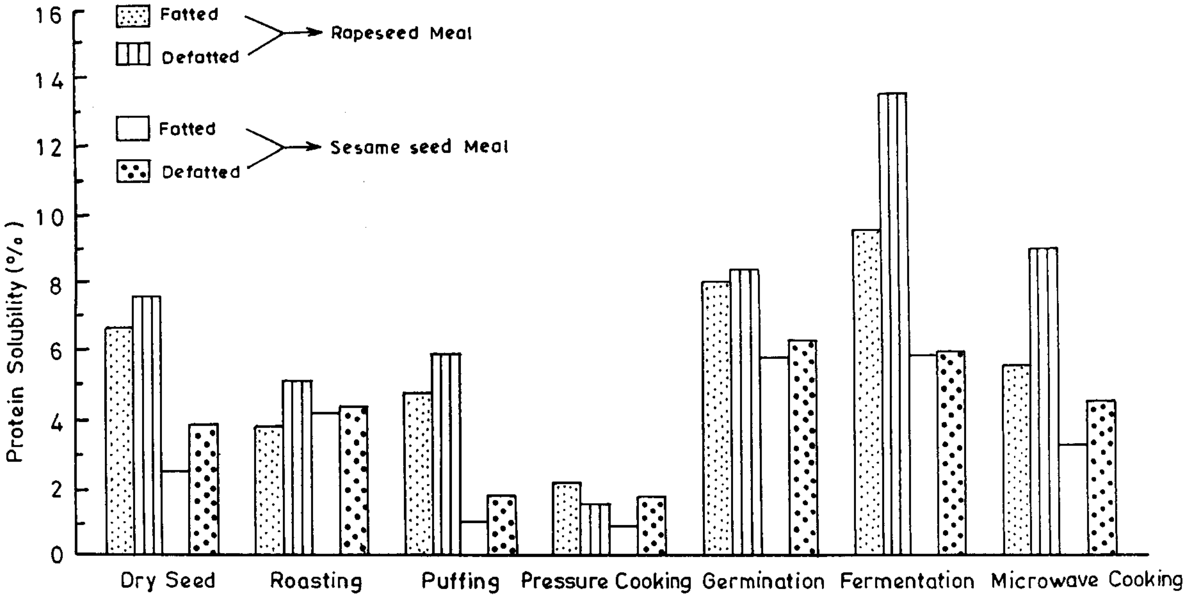

Figure 1. Effect of traditional processing on protein solubility of rapeseed meal and sesame seed meal.

meals (Table 2). The higher FAC of the cooked meals may be due to the dissociation and denaturation of proteins by heat, which unmask the nonpolar residues of the protein molecules (Rahma and Mustafa, 1988). Meals of germinated seeds had higher FAC values than the controls. Similar results in which an increase in FAC of germinated cow pea and mothbean flours occurred were reported by Padmashree et al. (1987) and Pawar and Ingle (1988).

Liquid retention is an index of the ability of proteins to absorb and retain water/oil, which, in turn, influences the texture and mouthfeel of foods, particularly comminuted meats, extenders or analogues, and baked doughs (Cheftel et al., 1985; Okezie and Bello, 1988). Processes that improve the FAC of rapeseed and sesame seed meals can be exploited for incorporation of these meal proteins into the above food products.

Protein Solubility. The full-fat meals of both rapeseed and sesame seeds showed maximum protein solubility in fermented products and minimum protein solubility for the pressure-cooked (Figure 1). All of the results were significant ($p > 0.05$) with respect to the controls. An increase of nitrogen solubility in fermented meals has been reported by various workers (Quinn and Beuchat, 1975; Canella et al., 1984). Fungal proteolytic activity would yield peptides and free amino acids with increased solubility in water. Germination also improved the protein solubility of rapeseed meal. Pawar and Ingle (1988) reported an increase in protein solubility in mothbean flour.

A reduction in protein solubility resulted due to heat processing except with microwave-cooked defatted meals. Proteins are sensitive to heat and undergo denaturation that results in low solubility, as in the case of heat-processed sunflower seeds (Lin et al., 1974), rapeseeds (Sosulski et al., 1976), and groundnut and soya seeds (McWatters and Holmes, 1979).

Protein solubility is an index of functionality and finds potential application in food products such as soups, beverages, and food cakes, in which gelation, emulsification, and foaming properties are required. The processing conditions in the present work, which enhance the protein solubility of rapeseed and sesame seed meals, could be adopted to use these meals in the above food formulations.

Foaming Properties. Germination and fermentation improved foam capacity (FC) of rapeseed meals (Figure 2). During germination, the amount of solubilized proteins increased, resulting in improved FC. Germination also improves the specific volume of foams, indicating better FC and air uptake during whipping.

Microwave treatment had a significant effect (a ~4-fold increase) on the FC of rapeseed meals. Mild treatments cause surface denaturation of proteins and keep them in solution, resulting in improved foaming properties as reported with soybean products (McWatters and Cherry, 1981). All other heat treatments considerably reduced FC. Yasumatsu et al. (1972) has also reported that heat processing diminished the protein solubility of soy protein by denaturing and reducing the FC. Foam was more stable for the raw flour than for the heat-processed meal. There was complete collapse of the foam in the heat-processed flour after an hour.

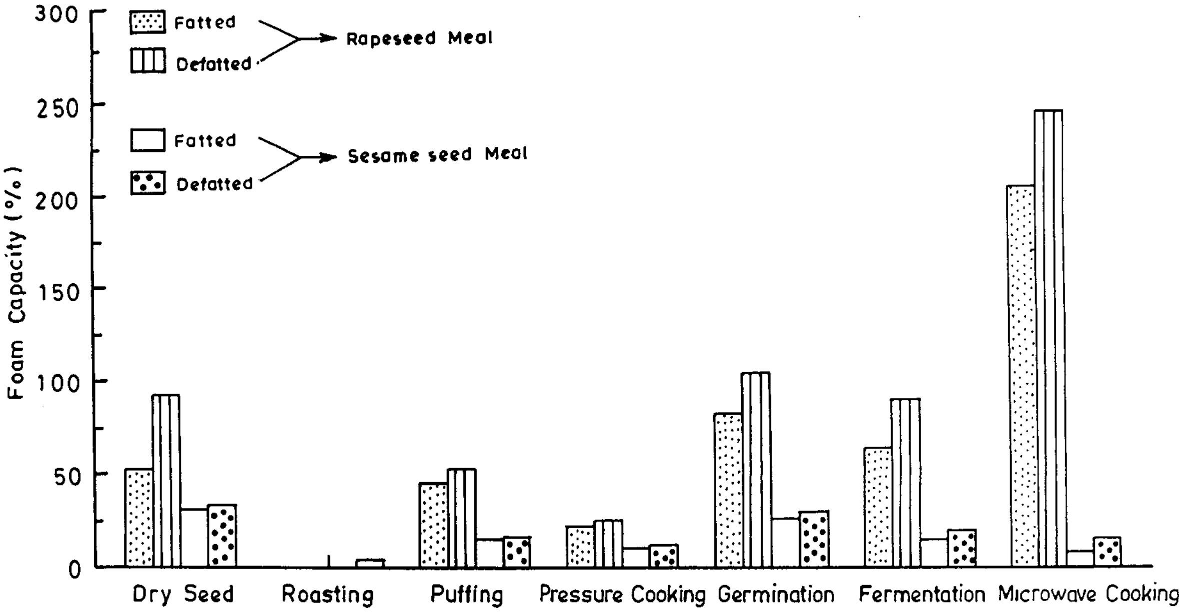

Figure 2. Effect of traditional processing on FC of rapeseed meal and sesame seed meal.

Table 3. Effect of Traditional Processing on FS (Percent) of Rapeseed Meals[a]

	fatted meal				defatted meal			
processing treatment	0 min	10 min	30 min	60 min	0 min	10 min	30 min	60 min
dry seed (control)	52.60 ± 0.57	41.32 ± 0.01	13.25 ± 0.30	5.68 ± 0.95	64.25 ± 1.25	53.50 ± 1.75	21.26 ± 2.25	11.11 ± 1.01
roasting	–[b]							
puffing	44.75 ± 2.06	21.75 ± 1.05	10.32 ± 0.03		53.25 ± 1.25	49.75 ± 1.50	11.15 ± 1.25	3.25 ± 0.01
pressure cooking	22.50 ± 1.91				25.75 ± 0.95			
germination	83.50 ± 1.29	53.50 ± 2.25	21.25 ± 1.75	10.75 ± 0.75	106.25 ± 7.50	80.25 ± 2.50	40.15 ± 2.50	17.25 ± 1.25
fermentation	64.75 ± 1.50	32.25 ± 1.50	10.55 ± 1.25	4.40 ± 0.25	91.25 ± 1.50	53.15 ± 1.10	15.15 ± 2.00	8.32 ± 1.20
microwave cooking	206.25 ± 6.94	113.25 ± 2.25	75.55 ± 1.25	50.25 ± 1.25	246.25 ± 4.78	135.15 ± 4.78	98.75 ± 3.15	61.17 ± 1.15

[a] Mean ± SD. [b] –, no foam was formed.

Table 4. Effect of Traditional Processing on FS (Percent) of Sesame Seed Meal[a]

	fatted meal				defatted meal			
processing treatment	0 min	10 min	30 min	60 min	0 min	10 min	30 min	60 min
dry seed (control)	31.25 ± 0.95	16.50 ± 0.25			33.75 ± 1.50	15.25 ± 0.13		
roasting	–[b]				3.75 ± 1.50			
puffing	15.75 ± 2.21				16.50 ± 1.95			
pressure cooking	10.50 ± 1.29				12.50 ± 2.08			
germination	26.50 ± 0.95				30.10 ± 1.25			
fermentation	15.25 ± 1.63				20.75 ± 1.91			
microwave cooking	7.75 ± 0.95				16.26 ± 1.71			

[a] Means ± SD. [b] –, no foam was formed.

Sesame seed meal showed poorer FC than did rapeseed meal. This may be due to the low protein solubility of sesame meal proteins. Different processing treatments led to a decrease in FC when compared to the control from sesame seed.

Foam stability (FS) was maximum for microwave-cooked rapeseeds at 60 min. Other heat treatments decreased the FS. With full-fat and defatted sesame seed meal, foams rapidly disappeared in all of the processed products (Tables 3 and 4). Defatting markedly increased FS in rapeseed meal. This investigation was in agreement with the report of Bencini (1986), who found that removal of lipids with hexane improved the FC of both chickpea and soybean flours.

The capacity of proteins to form stable foams with gas by forming impervious protein films is an important property. FS is important because the usefulness of whipping agents depends on their ability to maintain the whip as long as possible (Lin et al., 1974). Oil seed proteins are being increasingly used as aerating agents in whipped toppings, frozen desserts, and angel food and sponge cakes, etc., and consequently, processed rapeseed and sesame seeds can be utilized in these formulations on the basis of good foaming properties.

Emulsification Properties. Heat processing treatments reduced the emulsifying activity (EA) of meals (Table 5). The effects of heat processing in lowering the EA of some legume products such as soy, peanut, and winged bean flours have been reported by McWatters and Holmes (1979).

EA was highest in microwave-cooked defatted rapeseed and sesame seed meals. This may be due to lower heat exposure to seeds so that proteins are less denatured. McWatters and Cherry (1975) studied the effects of moist heat on the emulsifying capacity of full-fat peanut flours. They concluded that the dominant factors in determining emulsification capacity were temperature and time of heating.

All other treatments did not change EA appreciably in relation to untreated products. The emulsifying

Table 5. Effect of Traditional Processing on EA (Percent) of Rapeseed Meal and Sesame Seed Meal[a]

	rapeseed meal		sesame seed meal	
processing treatment	fatted	defatted	fatted	defatted
dry seed (control)	98.25 ± 0.95	97.00 ± 0.95	98.50 ± 1.29	80.75 ± 0.96
roasting	48.75 ± 1.50	49.25 ± 0.90	50.00 ± 1.41	50.50 ± 0.50
puffing	51.25 ± 1.55	51.25 ± 0.96	61.75 ± 0.96	50.75 ± 1.29
pressure cooking	50.50 ± 1.00	52.75 ± 0.50	61.50 ± 1.29	56.50 ± 1.92
germination	97.25[b] ± 0.82	99.00 ± 0.82	85.25 ± 1.26	82.75 ± 2.22
fermentation	60.00 ± 0.81	91.00 ± 1.63	81.25 ± 1.50	62.00 ± 1.42
microwave cooking	84.25 ± 0.95	100.00 ± 0.00	61.25 ± 1.50	96.00 ± 1.15

[a] Means ± SD. [b] Nonsignificant $p > 0.05$.

Table 6. Effect of Traditional Processing on Emulsion Stability (Percent) of Rapeseed Meal and Sesame Seed Meal[a]

	rapeseed meal		sesame seed meal	
processing treatment	fatted	defatted	fatted	defatted
dry seed (control)	94.25 ± 0.96	90.75 ± 1.30	51.24 ± 0.96	64.25 ± 0.96
roasting	49.25 ± 0.96	56.25 ± 0.50	49.75 ± 0.50	51.00 ± 1.83
puffing	51.00 ± 0.82	49.75 ± 1.71	51.25[b] ± 0.50	50.25 ± 0.96
pressure cooking	49.25 ± 0.96	55.50 ± 1.00	49.75 ± 0.50	55.50 ± 1.29
germination	91.25 ± 1.50	86.50 ± 1.00	49.75 ± 1.50	52.25 ± 0.96
fermentation	64.75 ± 0.50	61.00 ± 1.15	48.75 ± 1.50	51.75 ± 1.26
microwave cooking	100.00 ± 0.00	100.00 ± 0.00	49.75 ± 0.50	61.00 ± 1.83

[a] Means ± SD. [b] Nonsignificant $p > 0.05$.

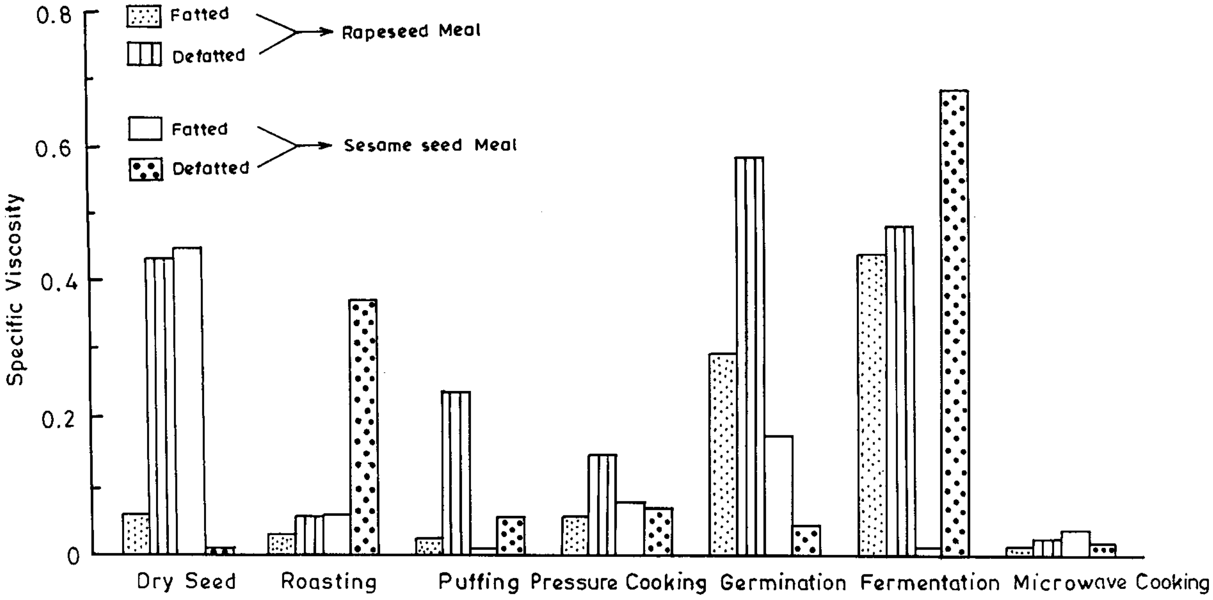

Figure 3. Effect of traditional processing on specific viscosity of rapeseed meal and sesame seed meal.

properties of oilseed proteins are discussed by various authors (McWatters and Holmes, 1979; McWatters and Cherry, 1981). They have been reported to be affected by many factors including solubility, pH, and concentration (Crenwelge et al., 1974).

EA in some treatments was more than ES, indicating that heating before centrifugation does not help to stabilize the emulsion in rapeseed and sesame meals prepared in the present study (Table 6).

The capacity of protein to enhance the formation and stabilization of emulsion is important for many applications in cakes, coffee whiteners, and frozen desserts. In these products varying emulsifying and stabilizing capacities are required because of different compositions and stresses to which these products are subjected.

Viscosity. All processing treatments significantly ($p < 0.05$) increased specific viscosity of defatted sesame seed meal. Heat treatments, however, reduced the relative viscosity of rapeseed meals and full-fat sesame seed meal (Figure 3). This may be due to the increase in temperature, which results in decreased viscosity by destabilizing both protein–protein and protein–water interactions (Huang and Kinsella, 1986).

Germinated and fermented rapeseed meals showed high viscosity properties. During fermentation and germination, not only the protein quantity but also the quality of the protein is altered, which may influence their flow behavior. In general, the viscosity behavior is influenced by size, shape, and hydration potential and by other chemical and physical states of the proteins in solution.

To conclude, the present work shows that among different traditional processing treatments, heat-processed (roasting and microwave cooking) rapeseed meals showed excellent WAC and FAC and microwave-cooked meals showed good FC. Protein solubility was improved by fermentation and germination processes. Sesame seed meals showed poor functional properties as compared to rapeseed meals except for viscosity, which was best in defatted sesame seed meal proteins.

These selected processes could be applied to rapeseed and sesame seed meals to improve the functionality of various food systems.

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