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Sesame Protein: A Review and Prospectus

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ABSTRACT

Sesame is one of the earliest condiments and crops grown for edible oil. Sesame is consumed directly as sweetmeat, a "peanut butter-like" product, a candy ingredient, bread condiments, and snack foods. The world production of sesame is about 2,000,000 metric tons. China and India are the largest producers but internally consume their production. Sudan is the largest exporter of seed. Sesame contains 50% oil, which is highly resistant to oxidation, and 25% protein, which has a unique balance of amino acids. Dehulling of sesame for human consumption is important since the hull contains 2-3% oxalic acid, which chelates calcium and has a bitter flavor. Dehulled, defatted meal contains 60% protein, is bland, and contains limited qualities of flatulence-causing sugars and high quantities of phytic acid. Aqueous processing yields isolated protein containing 72% protein and recovers 56% of the seed protein. Sesame protein is very stable to heat and contains large quantities of methionine. Sesame meal has a PER of about 1.35. Sesame is low in lysine and requires supplementation or can be blended with soy protein to give PERs nearly equivalent to casein. Sesame protein is composed of nearly 80% α-globulin and 20% β-globulin. Limited attempts have been made to characterize these 2 fractions. Sesame protein has low solubility that limits food applications in its native form. Sesame protein performs better than other oilseeds in baking applications. Production of sesame is limited to countries where labor is plentiful and inexpensive until indehiscent varieties and/or improved mechanical harvesting techniques are developed. However, intense breeding and engineering research programs are in progress.

INTRODUCTION

Sesame, *Sesamum indicum L,* may be the earliest condiment used and the oldest crop grown for edible oil. The seed has been called the "queen of the oilseed crops" because of the high yield of oil and quality of the seed, oil, and meal (1). Accounts of ancient history and mythology document early recognition of sesame seed as a source of high quality food. According to the Assyrians, the world was not created until the gods first refreshed themselves with sesame wine. Sesame was the symbol of immortality in early Hindu legend (2). Archeological evidence indicates that sesame was cultivated in Palestine and Syria around 3000 BC and in the civilizations of Babylonia, 1750 BC, and Indus Valley, 2500 BS (3). An Egyptian tomb bears a 4,000-year-old drawing of a baker adding sesame to bread dough. Archeologists have found sesame seed mash in the ruins of the Old Testament kingdom of Araret. In 1298 Marco Polo observed the Persians using sesame oil for cooking, body massage, medicinal purposes, illumination, cosmetics and lubricating primitive machinery.

WORLD PRODUCTION

Sesame is grown primarily in less developed tropical and subtropical areas of Asia, Mediterranean, and South America. Current world production is estimated at about 2,000,000 metric tons annually, placing sesame behind soybean, peanut, cottonseed, sunflower, linseed and rapeseed, in the quantity of world oilseed production (4,5). Acreage, yield and production on a world basis has largely remained the same over the past five years. In 1976, 1,900,000 metric tons were grown on 6,400,000 hectares with an average yield of 307 kg/hectare. The relative standing of the world's 10 leading sesame-producing countries in 1976 is summarized in Table I. India devotes the greatest acreage to sesame, but has one of the lower records for yield per hectare. India produces nearly 21.4% of the world sesame crop, followed by China at 19.6% and Sudan at 13.5%. Sudan is the major world exporter (6). Asia and Africa produce nearly 90% of the world supply of sesame. Most of the seed is consumed in the countries where it is produced; less than 5% of world production enters export trade (1).

Harvesting characteristics of sesame have precluded the development of a successful crop in the U.S. and other developed countries. The seed capsules of normal dehiscent (shattering) sesame varieties open at maturity. Considerable care is required to prevent excessive seed loss. The shattering of the seed pod is desirable in China and India where an adequate supply of cheap labor enables hand harvesting and threshing. The lack of uniform ripening of pods has further complicated mechanical harvesting techniques and breeding efforts. Seed pods at the base of the plant may be opening while the upper part of the plant is still flowering. Where mechanization is the basis for successful crop pro-

TABLE I

1976 Acreage, Yield and Production of Sesame in Selected Countries and the World (4)

Country and Continent	Acreage (1,000 hectares)	Yield (kg/hectare)	Production (1,000 metric tons)	% of World production
Top 10 Countries				
India	2,300	183	420	21.4
China	902	426	384	19.6
Sudan	798	332	265	13.5
Burma	741	186	137	7.0
Mexico	240	450	108	5.5
Nigeria	230	304	70	3.6
Ethiopia	160	438	70	3.6
Venezuela	140	443	62	3.2
Uganda	130	320	42	2.1
Afghanistan	43	930	40	2.0
Continents				
Asia	4,316	274	1,182	60.2
Africa	1,607	342	549	28.0
South America	182	486	89	4.5
Central America	269	512	137	7.0
North America	1	706	1	0.1
Europe	9	407	4	0.2
World	6,384	307	1,962	---

duction, as in North America, the lack of a mechanical harvesting procedure is the principal obstacle to widespread commercial production. The development of indehiscent varieties is one means to facilitate mechanical harvesting. Langham (7) in 1943 discovered a single indehiscent plant which has led to the development of a number of indehiscent varieties. A single Mendalian recessive gene controls the shattering characteristics, although, there is a strong genotype-environment interaction so that temperature and soil moisture affect genotypic expression (8). In general, indehiscent varieties have not been accepted because of lower yields; however, recent progress in sesame breeding has made the future of indehiscent sesame considerably more promising (9). Preliminary tests have indicated sesame yields 2200-2800 kg/hectare are possible in some southern areas of the U.S. and suggest that sesame may be an economical alternate crop for cotton.

FOOD USES

Dehulled sesame seeds are very small, sweet, and oleaginous, and are used directly for food in the Orient (10). Fried sesame seed may be mixed with sugar to form a sweetmeat or soup ingredient. A peanut butter counterpart is made from a paste of roasted sesame seed and called tachini (Tahena). Halvah (Halwa) is a candy made with tachini, sugar, egg albumin, gelatin, and Panama root juice (11). Halvah is a traditional food of Greek,, Turkish and other Near Eastern people. The pastel bar is a candy bar made of toasted sesame seed, honey and sugar and dates back to the days of Babylonia (12). Sesame is also used in high protein snack foods (13) and granola (14). Sesame seed is used extensively as a garnish on specialty breads, buns and rolls. Nearly all the seed imported into the U.S. is consumed in the bakery, confection, and sesame butter industries (10).

On a world-wide basis, sesame seed is grown primarily for its oil content. Sesame oil has a pleasant, mild taste and is remarkably stable. It is a natural salad oil requiring little or no winterization and is one of the few vegetable oils that can be used without refining. These are factors of increasing importance as energy costs escalate. Also, interest is developed in the use of refined sesame oil as a "natural oil." Sesame oil has a high content of polyunsaturated fatty acids, 43% oleic and 43% linoleic. The rate of oxidation is much slower than expected due to the natural antioxidant, sesamol (1). The oil has been used for cooking, shortening and margarine, as a soap fat, in pharmaceuticals and as a synergist for insecticides. The oil-free meal is used extensively in livestock feed. It is also palatable to humans and may be fermented and consumed directly as in India and Java (15).

SEED COMPOSITION

The seed composition of sesame is well established (6, 16, 17). Oil content ranges from 45 to 63%, averaging about 50% oil; protein content ranges from 19 to 31% with an average of about 25% (18). The protein factor of total nitrogen times 6.25 is generally applied to sesame protein. Although this factor is high for some other oilseed proteins, it is nearly appropriate for sesame since Prakish and Nandi (19) have shown that α-globulin, which comprises 65-80% of sesame protein, is 15.9% nitrogen. In general, Indian varieties tend to be lower in protein and higher in oil than Sudanese varieties which generally appear in the export market (Table II). Most oilseeds show a negative correlation between oil content and protein content; sesame is no exception. For each 1% average increase in protein content, there is a corresponding average decrease in oil content of 0.85% (23).

Hull material accounts for 15 to 20% of the whole sesame seed (21,22,24) and contains large quantities of oxalic acid, calcium, and other minerals as well as fiber. Since the hull has an intense bitter taste and oxalic acid binds to calcium rendering it nutritionally unavailable, it is desirable to remove the hull if the seed is used in human foods. Black varieties of sesame contain higher levels of oxalic acid and fiber and lower protein levels than white varieties (25). When properly dehulled, oxalic acid content is reduced from 2.5-3.0% to less than 0.25%. Expeller-pressed, dehulled sesame will contain greater than 56% protein and dehulled, prepressed, solvent-extracted meal will contain more than 60% protein. Defatted sesame meal is generally utilized as animal feed and oftentimes as fertilizer. Only in India is sesame meal extensively used in human foods, although interest is continually increasing in food uses of sesame protein.

Whole sesame seed contains about 14% carbohydrate (21). Wankhede (26) found that the carbohydrate fraction of sesame contained 3.24% D-glucose, 0.06% D-galactose, 2.63% D-fructose, 0.17% sucrose, 0.24% raffinose, 0.23% stachyose, o.59% planteose, 0.38% sesamose, 0.16% pentasaccharides and 0.08% hexasaccharides on a moisture-free basis. The levels of stachyose and raffinose of defatted soybean meal range between 4-5% and 1-2%, respectively (27).

TABLE II

Composition of Seasame Seed Products[a]

	Sudanese White (%)		Indian Black (%)				
	Whole seed[b]	Dehulled seed[b]	Whole seed[c]	Dehulled seed[c]	Hull[d]	Dehulled expeller-pressed[c]	Dehulled hexane-extracted[c]
Fat (ether extractable)	53.28	57.50	54.25	63.36	10.65	10.62	0.43
Protein (N x 6.25)	25.02	29.90	20.20	23.44	8.35	57.75	60.22
Ash	5.42	3.46	6.18	2.41	23.80	6.58	6.53
Crude fiber	4.08	3.04	4.49	2.46	19.31	5.41	5.29
Oxalic acid	2.71	0.36	2.51	0.13	14.93	0.25	0.28
Calcium	0.98	0.23	1.31	0.22	10.18	0.33	0.37

[a]Moisture-free basis.
[b]Adapted from reference 20.
[c]Adapted from reference 21.
[d]Adapted from reference 22.

TABLE III

Amino Acid Composition of Dehulled Sesame Products

	Content (g/16 g N)		
Amino acid	Meal[a]	Isolate[b]	FAO reference protein[c]
Cystine	2.1	0.8	2.0
Argenine[d]	9.0	11.7	2.0
Lysine[d]	3.5	2.1	4.2
Histidine[d]	2.4	2.1	2.4
Aspartic acid	7.4	7.3	
Glycine	6.8	8.9	
Serine	4.1	4.2	
Glutamic acid	15.5	20.3	
Threonine[d]	3.9	3.3	2.6
Alanine	5.3	4.3	
Tyrosine	4.3	3.7	
Methionine[d]	3.5	2.9	2.2
Valine[d]	4.6	4.6	4.2
Phenylalanine[d]	6.3	4.2	2.8
Isoleucine[d]	4.7	3.6	4.2
Leucine[d]	7.4	6.6	4.8
Trytophane[d]	1.9	1.8	1.4
Proline	---	4.6	

[a]See reference 21.
[b]See reference 40.
[c]See reference 18.
[d]Nutritionally essential.

PROCESSING

In those areas where sesame is primarily processed for its oil content, the seed is not dehulled; rather, the entire seed is crushed. However, in areas such as India where the meal is an important food, seed hulling is an important process step for three reasons: 1) the removal of the hull reduces the content of oxalic acid which is associated with the outer epidermal layer; 2) the protein content of the meal is increased since the hull is primarily composed of fiber (28); and 3) dehulling improves enzymatic digestibility (29).

The small size of the sesame seed makes dehulling a difficult process. Numerous procedures have been developed with varying degrees of success. One traditional method is to soak the seed in water until the seed coat bursts and the hulls float free of the seed. Flotation separation of hulls from seed is enhanced by adjusting the density of the water with salt so that seeds float and hulls sink (30). Another traditional method incorporates abrasion of soaked seed and washing the hulls away over screens (21, 24, 31). Hot, dilute alkali such as sodium hydroxide, sodium borate, or sodium hypochlorite have also been used to loosen or desintegrate the hulls (32-35). The contact time of the seed with hot alkali is critical to prevent reduction in available lysine and discoloration. A contact time of 1 min in 0.6% sodium hydroxide is adequate (22). Aqueous dehulled seed must be dried and requires large expenditures of energy unless sun-drying is used as in India. Nonaqueous methods, such as sieving or air classification, have also been used to remove the hulls after flaking and oil extraction (36).

Sieving and air classification of dehulled sesame meal has been utilized to produce two fractions with different protein contents (37). The coarse fractions were ca. 45% protein and comprised ca. 40% of the starting material. The fine fractions were about 65% protein and comprised ca. 60% of the original.

Liggett (38) has patented a process for extraction of oil from crushed sesame seed with hot calcium hydroxide solution. Sesame protein is substantially soluble in alkaline solution and a high quality protein precipitates when acidified to the isoelectric point. The protein is recovered by centrifugation and the oil separated from water by decanting. Similar aqueous processing technology was developed at the Food Protein Research and Development Center, Texas A&M University (39,40) to isolate a sesame protein fraction containing 78.2% protein with less than 2.1% crude free lipid. Extraction was achieved by dispersing 1 part of the ground sesame with 3 parts solvent in an aqueous dispersion at pH 10.5 for 30 min at 80 C. The oil, soluble protein, and insoluble fibrous residue were simultaneously separated using a 3-phase centrifuge. The protein was precipitated from the alkaline extract by adjusting to pH 4.5. Approximately 56% of the seed protein was recovered as isolated protein.

NUTRITIONAL QUALITY

The major asset of sesame protein is its unique nutritional character. The dehulled, defatted meal contains greater than 60% protein, which is high in methionine, cystine and tryptophane, and is bland and white in color. On the other hand, sesame meal is low in lysine and may contain high amounts of oxalic and phytic acids. High levels of selenium (41) and lead (42) have also been reported.

An unusual feature of sesame is that it generally contains 2-3% oxalic acid and 1-2% calcium, which are primarily in the hull. The simultaneous presence of large amounts of calcium and oxalic acid makes it highly probable that the two exist as calcium oxalate. It has been assumed that ½ to 2/3 of the calcium in sesame exists as the oxalate salt (43). Calcium bound as the oxalate salt is not biologically available, which is particularly important in the feeding of infants. Since oxalate is present primarily in the hull, dehulling results in low levels of residual oxalate. Albino rats fed diets containing high levels of sesame hulls have exhibited retarded growth and increased cholesterol content in blood serum and liver (44). Dehulling improves nutritional and flavor characteristics of the meal, as well as reducing the fiber content, increasing the protein content and rendering a glossy white color.

Defatted sesame contains more than 5% phytic acid compared to defatted soybean meal at 1.5% (45). Phytate reduces the biological availability of zinc, calcium, magnesium and perhaps iron and complexes with protein rendering it less soluble (46). Sesame meal can cause nutritional problems when used in chicken feed (1). There is evidence indicating that phytate-protein complexes are less subject to proteolytic digestion than unbound protein (47). Apparently, phytate in sesame meal is not strongly complexed to protein, but is not readily extracted by neutral aqueous solvents because it exists primarily as an insoluble magnesium complex. Since 90% of the phytate in defatted sesame meal is insoluble in water, aqueous extraction processing of isolated sesame protein may be a means of reducing phytic acid content.

Sesame seed has a PER of 1.86; sesame meal, 1.35; and isolated protein 1.2 (48). The biological value of sesame seed protein is 62.0, which is lower than that of soybean and sunflower (49). The net protein utilization is 53.4, corresponding to 81.0 for milk. Sesame seed protein, however, is of particular interest in that its makeup of amino acids (Table III) is complementary to that of most other oilseed proteins. Sesame meal and isolated protein have particularly high contents of methionine, 2.5-4.0%, and total sulfur-containing amino acids, 3.8-5.5% (1). Lysine is the first limiting amino acid. Lysine is deficient in almost all varieties; although sesame varieties with darker seed coats possess higher lysine. Isoleucine is the only other amino acid lower than the quantity in the FAO reference protein. Tryptophane, which is limiting in other proteins, is present in generous quantities in sesame. Rastogi and Krishna Murti (50) have shown the PER for isolated sesame protein is less than that of sesame meal. The isolate contains less of the essential amino acids than does the meal (Table III). This is a common occurrence in oilseed proteins. However, these authors also reported evidence indicating papain hydrolysis of isolated sesame protein increased the PER to nearly the same level as casein (50).

Amino acid availability of sesame protein is affected by processing methods. Dry heat treatment reduced enzymatic digestibility, whereas wet heat treatment (50% moisture, 121 C for 1 hr) improved digestibility. This has been shown to occur in several other plant proteins (28). Villegas et al. (28) report that methionine availability increased with heat treatment. Available lysine content of sesame flour exhibits remarkable stability to heat. Shamanthaka Sastry et al. (29) have shown that the loss of available lysine is only 9% in autoclaving sesame flour at 10% moisture, 120 C for 60 min. The expelling process has very little adverse effect on available lysine. Actually the heat treatment inherent to the expelling operation has a beneficial effect on sesame protein by increasing the protein efficiency (22). In vitro digestibility by trypsin of isolated sesame protein before and after autoclaving are the same indicating the absence of any thermoliable trypsin inhibitor (50).

The effect of supplementing sesame protein with those amino acids that are deficient has been the subject of several investigations. Evans and Bandemer (51) supplemented sesame seed with lysine and isoleucine and improved protein nutritive value to nearly that of casein. Methionine supplementation did not significantly alter protein nutritive value as was expected from the amino acid distribution inherent to sesame. Shamanthaka Sastry et al. (29) reported that a supplementation of 1.25 g L-lysine HCl/100 g sesame protein in defatted meal increased the PER from 60% of that of skim milk to 90%. Joseph et al. (52) have shown that when sesame meal was fortified with lysine to bring the lysine content to 4.2%, which is the same level as in the FAO reference protein, the PER increased from 1.70 to 2.14. Fortification with lysine to a level of 8.2%, the level of lysine in casein, increased the PER to 2.91. Clearly, if sesame protein is the majority dietary source of protein, supplementation with lysine increases nutritional value.

The use of a protein source high in sulfur-containing amino acids as a food adjunct is a valuable means of improving diets based upon legumes. The use of sesame meal as a food adjunct yields an even and more adequate release of amino acids in the digestive tract in contrast to the use of free methionine (28). Supplementing with protein rather than individual amino acids contributes quantities of other essential amino acids and bulk protein. Free methionine is also known to have an adverse effect on flavor in some food products. Sesame meal flour is one of the few known sources rich in methionine and tryptophane. Blends of peanut/chickpea (53,54), wheat/chickpea (55), rice/chickpea (55), peanut/soybean (56), sunflower/maize (57) and cowpea/rice (58) have all shown improved nutritional qualities with supplementation of sesame meal. Probably more significant, however, is the finding that a simple blend of 1 part sesame and 1 part soy protein has about the same protein nutritive value as casein (51). The high lysine and low methionine contents of soy protein is complementary to sesame protein.

PROTEIN BIOCHEMISTRY

Ritthausen (59) in 1880 was the first to attempt to characterize sesame protein. Protein was extracted from hydraulic press cake by suspending the cake in 10% sodium hydroxide solution at different temperatures, clarifying the extract and precipitating the protein by increasing temperature and/or reducing the pH. Ritthausen reported the carbon, hydrogen, oxygen, nitrogen and sulfur contents of the isolated protein. Sesame protein was largely ignored from 1880 until 1927 when Jones and Gersdorff (60) isolated 2 different globular proteins in sesame press cake, α-globulin and β-globulin. Sesame cake was suspended in 10% sodium hydroxide and clarified. The globulins were fractionally precipitated at 20 and 60% ammonium sulfate saturation of the extract. The α-globulin fraction was obtained in the crystaline form of tetragonal pyramids and β-globulin as an amorphous white powder. Sesame cake contained 4 times as much α-globulin as β-globulin. To date, no published data is available on the albumin fraction of sesame protein.

Nath and Giri (61-63) have subsequently shown that α-globulin and β-globulin isolated by fractional precipitation with ammonium sulfate gave electrophoretically

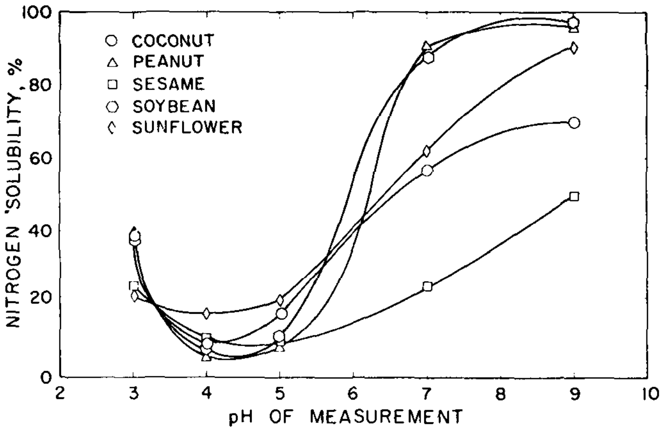

FIG. 1. Nitrogen solubility profiles for five oilseed flours.

heterogenous mixtures of protein. The α-globulin fraction contained a unique protein and β-globulin, two unique proteins. A fourth protein was equally divided between both fractions.

Prakash and Nandi (19) isolated α-globulin, 95% pure, from sesame seed. The α-globulin protein comprised 65-70% of the total seed protein. This group studied the association-dissociation, aggregation and denaturation phenomenon of α-globulin in various salt solutions (64), sodium duodecyl sulphate (65), urea and quanidine hydrocholoride (66), centrimonium bromide (67) and acid and base (68). The α-globulin protein has been characterized as: having an isoelectric point of 4.9; having a nitrogen content of 15.9%; and consisting of 12 different subunits with molecular weights ranging 8,000-85,000 daltons, which are predominantly associated by hydrophobic interaction. Prakash and Nandi (19) estimated the molecular weight of α-globulin to be 250,000±15,000 by sedimentation equilibrium and sedimentation velocity methods. This is considerably lower than the estimate by Ventura and Lima (69) of 450,000±30,000 using sedimentation and diffusion techniques.

FUNCTIONALITY

Present knowledge of sesame protein functionality is limited to unfractionated, native protein and to studies of viscosity, whippability, solubility and potential as a bread flour supplement. Sesame protein is substantially insoluble at low pH and very soluble at high pH (70). However, the solubility profiles of various oilseed proteins (Figure 1) indicate sesame protein is less soluble at high pHs than other common oilseed proteins (71). Protein solubility of sesame meal can be increased by enzymatic hydrolysis as with other proteins. Hydrolysis with commercial proteases from *Trametes sanquina* for 5 hr at 45 C will increase protein solubility of sesame meal from 7.2 to 64.1% (75). Natural hydrolyzed sesame meal has a bland flavor and aroma which is contrary to most enzymatically hydrolyzed oilseed proteins. Sesame flour has low foam viscosity in aqueous dispersions (71). Whippability in the absence or presence of sugar is low compared with other major oilseed proteins (71). The lack of solubility in the native protein results in functional applications different from other oilseed proteins with greater solubility.

The insoluble nature of sesame contributes to desirable bread-making qualities. Generally, insoluble oilseed proteins function better in bread supplementation than soluble protein. Most oilseed flours must be heat treated to reduce their impairment of loaf volume and crumb grain. However, heat treatment reduces available lysine and darkens color. Sesame flour, heat-treated or nonheat-treated, is lighter in color than cottonseed, peanut, or sunflower counterparts. Rooney et al. (72) have shown sesame flour to be more compatible with wheat flour than other oilseeds in producing bread with good loaf volume and crumb texture (Table IV). The protein content of bread was increased from 14 to 20% using nonheat-treated sesame flour without significantly impairing bread quality. Heat-treating sesame flour reduced loaf volume and darkened crumb color. Sesame seed should be dehulled for bread flour supplementation to preclude impairment of bread-making quality (73).

RESEARCH NEEDS

Improvement in yield of indehiscent varieties is important in the long term. In the short term, the yield of dehiscent varieties is nearly sufficient to justify U.S. production. A mechanical harvesting technique that reduces harvest losses of both dehiscent and indehiscent varieties is the key to a successful domestic crop in the U.S.

The anticipated advent of a domestic U.S. sesame crop is creating significant interest by U.S. food manufacturers in developing new food products with sesame. Nutritional and functional properties of sesame protein and oil are unique. The high yield of premium quality oil with minimal processing requirements is particularly attractive. The complementary nutritional character of sesame with soy is probably the most important property of sesame protein. Sesame is the single readily available source of protein high in sulfur-containing amino acids. However, more research is required in processing to improve removal of oxalic acid, reduce phytic acid content and identify and remove low levels of bitter principles. Improving the solubility, emulsification, gelling and whipping properties is possible. Better flavor and color of sesame over soy protein are attributes that clearly contribute to the potential success of sesame protein. The fact that sesame protein is more compatible than other oilseed protein in baked products creates an immediate potential market. A better understanding of the biochemical nature of sesame protein is necessary to extending food applications. Sesame protein is one of the least researched oilseeds. Published reports are limited in number and often are contradictory and incomplete.

Although present production of processed sesame protein ingredients is currently nonexistent in developed countries, reliance on sesame meal as a food source in the Orient, Far East, and Africa continues to increase. The

TABLE IV

Bread-Baking Properties of Oilseed Wheat Flour Blends (72)

	Specific loaf volume (cc/g)				Reflectance value (%)			
	no heat		heat		no heat		heat	
Protein level (%)	17.5	20.0	17.5	20.0	17.5	20.0	17.5	20.0
Cottonseed	5.65	4.87	6.50	5.65	49	45	45	40
Peanut	6.28	5.86	6.30	5.91	56	56	51	47
Sesame	6.52	5.79	6.25	5.71	56	55	50	48
Sunflower	5.67	3.22	6.18	4.56	44	30	45	28
Control (wheat flour)	6.7				59			

anticipation of a domestic supply of sesame in the U.S., increasing worldwide utilization of sesame protein for food, and increasing knowledge of functional, nutritional, and biochemical properties of sesame protein contribute to the optimistic future of sesame as a source of food protein.

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