SOYBEANS AND OTHER OILSEEDS

1. Introduction

Soybeans, cottonseed, peanuts, and sunflowers are the four principal oilseed crops grown in the United States. Except for cottonseed, these are consumed directly as foods to varying extents, but all serve as sources of edible oils commonly referred to as vegetable oils. Although not normally considered to be an oilseed, corn provides the second largest quantity of vegetable oil used domestically in foods. Selected data on corn oil are therefore included for comparison with oilseed oils. After removal of the oils, the resulting oilseed meals are rich in proteins and find widespread use as animal feeds. Food uses of oilseed proteins derived from meals are relatively small and are limited to soybeans and peanuts. Table 1 summarizes botanical names, geographic distribution, and the main uses of these four oilseeds.

Soybeans, the principal oilseed crop in the United States, are believed to have been domesticated in the eastern half of northern China around the eleventh century BC or earlier. They were later introduced and established in Japan and other parts of Asia, brought to Europe, and introduced to North America in 1765 (1). Soybeans became an established oilseed crop in the late 1920s, attaining commercial importance during World War II. Cotton has a long history that can be traced back as far as 3000 BC through spun cotton yarn found in the Indus valley. It is indigenous to many parts of the world, and its establishment as an oilseed in the United States is associated with the invention of the cotton gin by Eli Whitney in 1794. Peanuts or groundnuts likely originated in South America and were later introduced to Africa and Asia. Subsequent cultivation of peanuts in North America was started with plants imported from Africa. Sunflowers are native to North America and probably originated in the southwestern United States. They were introduced to Spain by the early Spanish explorers and then spread to Russia, where they became established as an oilseed crop. Sunflowers became a significant U.S. oilseed crop as late as 1967, upon the development of varieties having high oil content and improved agronomic characteristics such as increased resistance to diseases and pests.

2. Physical Characteristics

Plants and seeds of the four oilseeds vary in growth habit, size, shape, and other features. A common feature of the four oilseeds is storage of the bulk of the protein and oil in distinct membrane-bound, subcellular organelles called protein bodies and lipid bodies, respectively, as illustrated for soybeans in Figure 1. Although not shown, the protein bodies contain inclusions referred to as globoids ($\leq$0.1 μm dia) that are storage sites for phytate and cations such as potassium, magnesium, and calcium (3). During germination, the contents of the storage organelles are mobilized and utilized by the growing seedling.

2.1. Soybean. *Plant.* Soybeans grow on erect, bushy annual plants, 75–125 cm high, having hairy stems and trifoliate leaves. The flowers are white or purple or combinations thereof. Growing season varies with latitude and is 120–130 d in central Illinois.

Seeds. Seeds are produced in pods, usually containing three almost spherical-to-oval seeds weighing 0.1–0.2 g. Commercial varieties have a yellow seed coat plus two cotyledons, plumule, and hypocotyl-radicle axis. The cotyledons contain primarily protein and lipid bodies (see Fig. 1).

2.2. Cottonseed. *Plant.* Cotton grows as an annual or perennial herb or shrub, sometimes tree-like, 0.25–3 m or more in height depending on species, with three-, five-, or seven-lobed leaves with white to yellow or purple-red flowers. The herbage is irregularly dotted with pigment glands. The growing season for Upland cotton grown in the United States is 120 d.

Seeds. The seeds are produced in leathery capsules (bolls), covered with lint and fuzz fibers. The seeds are ovoid, 8–12 mm long having brown to nearly black seed coats. The interior of the seed consists of a radicle, hypocotyl, epicotyl, and two cotyledons. Cotyledon tissue contains protein and lipid bodies. Most varieties contain pigment glands (storage sites of gossypurpurin and gossypol) 100–400 μm long (4). Glandless varieties of cottonseed, which lack the toxic gossypol, are available but are not grown commercially despite having undergone extensive research and development (5).

2.3. Peanut. *Plant.* Peanuts grow on annual herbaceous plants, bushy upright (erect) or spreading (runner) types, 25–50 cm high with bijugate leaves, hairy stems, and bright yellow flowers having peduncles that bend after fertilization and push the pods underground, where they develop and ripen. The growing season is 120–140 d.

Seeds. The seeds are produced in pods containing two or three seeds. The kernels are almost spherical to roughly cylindrical (0.4–1.1 g each) and consist of a thin coat (testa) containing two cotyledons and the embryo. Cotyledons contain protein bodies, lipid bodies, and starch granules.

2.4. Sunflower. Two types of sunflowers are grown in the United States. Varieties grown for oilseed production, ca 85% of crop, are generally black-seeded, having thin seed coats that adhere to the kernels. These contain 40–50% oil and ca 20% protein. Nonoilseed varieties, ca 15% of crop, sometimes referred to as confectionery, striped, or large-seeded sunflowers, have striped, relatively thick hulls that do not adhere to the kernels. These contain 20–30% oil and are usually larger than seeds of oilseed varieties.

Plant. The sunflower is an erect annual, 1–4 m high, having alternating leaves. The heads are $\leq$30 cm wide having orange-yellow rays and dark center disks. The growing season is ca 120 d.

Seeds. The sunflower seed (achene) is four-sided and flattened, ca 9 mm long $\times$ 4–8 mm wide, having a black or striped gray and black seed coat (pericarp) enclosing a kernel. The kernel contains protein and lipid bodies.

3. Chemical Composition

Compositions of the four oilseeds are given in Table 2. All except soybeans have a high content of seed coat or hull. Because of the high hull content, the crude fiber content of the other oilseeds is also high. Confectionery varieties of sunflower seed may contain up to 28% crude fiber on a dry basis (8). Soybeans differ from the other oilseeds in their high protein and low oil content. All these oilseeds, however, yield high protein meals when dehulled and defatted.

3.1. Proteins. The proteins found in the four oilseeds are complex mixtures consisting of four characteristic fractions having molecular weights of ca 9,000–700,000, as illustrated by the ultracentrifuge pattern for soybean proteins (Fig. 2). The 7S and 11S fractions usually predominate, but in sunflower seeds, the 2S and 11S (helianthinin) proteins are the main fractions (11). The 7S and 11S fractions are considered to be storage proteins and are located in the protein bodies (12). Of the four oilseeds, the proteins of soybeans are the best characterized. The principal portion of soybean 7S fraction, β-conglycinin, consists of at least seven isomers resulting from various combinations of three subunits, ie, α, α', and β. These are $\alpha\beta_2$, $\alpha'\beta_2$, $\alpha'\alpha\beta$, $\alpha_2\beta$, $\alpha\alpha'_2$, α_3, and β_3 (13,14). Based on the sizes of the subunits, the β-conglycinin isomers have molecular weights between 126,000 and 171,000.

The 11S molecule in soybeans, also called glycinin, is more complex than β-conglycinin. It consists of six subunits (ca 60,000 mol wt) each of which contains an acidic polypeptide (37,000–44,000 mol wt) linked to a basic polypeptide (17,000–22,000 mol wt) by a single disulfide bond. The subunits are synthesized as single polypeptides, proglycinin precursors, which undergo proteolytic cleavage to form the two polypeptide chains after the precursors enter the protein bodies (15). Five glycinin genes have been cloned and sequenced (16). The relative sizes of the primary polypeptides constituting the principal soybean proteins are shown in the gel electrophoresis diagram of Figure 3.

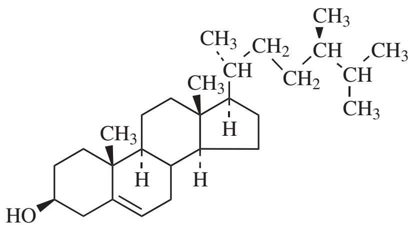
Arachin, the counterpart of glycinin in peanuts, consists of subunits of 60,000–70,000 mol wt which on reduction with 2-mercaptoethanol yield polypeptides of 41,000–48,000 and 21,000 mol wt (17) analogous to the behavior of glycinin. In addition to the storage proteins, oilseeds contain a variety of minor proteins, including trypsin inhibitors, hemagglutinins, and enzymes. Examples of the last are urease and lipoxygenase in soybeans.

Amino acid compositions of the four oilseeds are given in Table 3 along with the amino acid requirements for humans suggested by a Joint FAO/WHO/UNU Expert consultation.

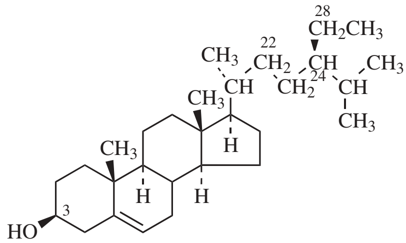
3.2. Lipids. Representative fatty acid compositions of the unprocessed triglyceride oils found in the four oilseeds are given in Table 4. Cottonseed, peanut, and sunflower oils are classified as oleic–linoleic acid oils because of the high (>50%) content of these fatty acids. Although the oleic and linoleic acid content of soybean oils is high, it is distinguished from the others by a content of 4–10% of linolenic acid, and hence is called a linolenic acid oil.

In addition to the triglycerides, the four oilseeds also contain phosphatides. For example, soybean oil containing 1.47% phosphatides consists of 48.9% phosphatidylcholine, 27.0% phosphatidylethanolamine, 21.9% phosphatidylinositol and 2.2% phosphatidic acid (24). Total phosphatides of cottonseed and peanut kernels are estimated to be 1.5–1.9 and 0.8%, respectively (25).

Sterols are present in concentrations of 0.2–0.4% in the oils. Compositions are given in Table 5. The sterols exist in the seeds in four forms: free, esterified, nonacylated glucosides, and acylated glucosides. Soybeans contain a total of 0.16% of these sterol forms in the ratio of ca 3:1:2:2 (27).



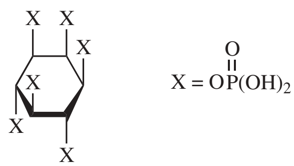
(**1**)



(**2**)

3.3. Carbohydrates. Oilseeds contain two types of carbohydrates: soluble mono- and oligosaccharides and largely insoluble polysaccharides. Contents of oligosaccharides of defatted meals are given in Table 6. Sucrose, raffinose, and stachyose are the principal sugars present. The polysaccharide content, not including crude fiber, is roughly equal to the total carbohydrates minus the total oligosaccharides, and these values range from about 12 to 22% of the flours.

3.4. Minor Constituents. All four oilseeds contain minor constituents that affect the use of the defatted seeds, especially in feeds and foods. Percentages of phytic acid [*83-86-3*] (**3**), for example, are soybean, 1.0–1.5 (30); cottonseed kernels, 2.2–3.8 (25); peanut kernels, 0.8 (25); and sunflower, 1.6–1.7 (31).

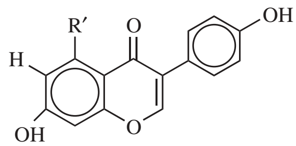


(**3**)

Glanded cottonseed kernels contain 1.1–1.3% gossypol (19) plus related pigments that affect nutritional properties and color of the oil and meal. Cottonseed also contains the cyclopropenoid acids, malvalic and sterculic acids, which exist as glycerides and are concentrated in the seed axis (32).

Soybeans contain only 1–25 ppm of phenolic acids (33) whereas defatted sunflower meal contains 2.7% chlorogenic acid, 0.38% quinic acid, and 0.2% caffeic acid (34). Chlorogenic acid turns from yellow to green and finally to brown as the pH is raised from 7 to 11. Interaction of chlorogenic acid with sunflower proteins results in the formation of green-to-brown isolates, thereby limiting use in foods (35).

The isoflavones genistein [*446-72-0*] (**4**), daidzein [*486-66-8*] (**5**), and glycetein (**6**) occur in soybeans in the form of malonyl glucosides, acetylated glucosides, glucosides, and aglycones; total concentrations range from 1200–4200 μg/g for different varieties (36).



(**4**) R = H, R′ = OH
(**5**) R = R′ = H
(**6**) R = OCH_3, R′ = H

Soybeans and peanuts also contain saponins, which are glucoside derivatives of triterpenoid alcohols (37). Saponins range from 0.09 to 0.32% in 457 soybean varieties (38).

4. Harvesting and Storage

4.1. Soybeans. The U.S. soybean crop is grown from Minnesota to Florida. Primary production occurs in the Midwest, ie, in Illinois, Iowa, Minnesota, Indiana, Ohio, and Missouri. Harvest begins in September or October. Ideal moisture for harvesting is 13%, and the crop can be successfully stored at this moisture content until the following summer. Soybeans at $\leq$12% moisture can be stored for two years or more with no significant deterioration although the entire crop is usually processed in little over a year after harvest. Beans having moisture above safe storage limits are dried or placed in aerated bins for gradual moisture reduction.

Soybeans are trucked from the farm to country elevators and are then moved by truck or rail to processing plants, subterminal elevators, or terminal elevators. From the terminal elevators the beans are shipped by rail or barge to export elevators or processors.

Soybeans are stored in concrete silos 6–12 m dia with heights of $\geq$46 m. The silos are often arranged in multiple rows, and the resulting interstitial silo areas are likewise used for storage. In bulk storage, seasonal temperature changes cause variations in temperature between the different portions of the grain mass; for example, in the winter, soybeans next to the outer walls are colder than those in the center of the silo. Such temperature differences initiate air currents that transfer moisture from warm to cold portions of the seed mass. Thus, bulk soybeans originally at safe moisture concentrations may, after storage, have localized regions of higher moisture that cause growth of microorganisms, which in turn can lead to heating. If these conditions persist, the beans turn black and may eventually ignite. Such seasonal moisture transfer also occurs with other oilseeds. In commercial practice the temperature is carefully monitored and, when it rises, the beans are either remixed or processed. Aflatoxin contamination is not a problem as it is with cottonseed and peanuts. Although fungi invade soybeans stored at high moisture and temperatures, *Aspergillus flavus* does not grow well on soybeans and aflatoxin levels are negligible. Other mycotoxins, eg, zearalenone, zearalenol, diacetoxyscirpenol, deoxynivalenol, and T-2 toxin, can be found in soybeans damaged by molds in the field when abnormally warm and humid weather prevails and delays harvesting (39).

4.2. Cottonseed. In the United States, cotton is grown in the southern and western states, mainly in Texas, California, Mississippi, Arizona, and Louisiana. Harvesting begins in late July when the ripened boll bursts and the cotton dries and fluffs. The harvest is usually completed by the end of December. After picking, the cotton is processed in gins to separate the lint from the seed. Moisture, temperature, initial quality, previous history, and length of storage determine how long cottonseed can be held before processing. Moisture is the most important factor. For safe storage, moisture should be $<10\%$. Cottonseed is usually stored in Muskogee-type warehouses, ie, low, flat metal buildings having roofs that slope close to the angle of repose of cottonseed, and that are equipped with aeration and temperature-monitoring systems. High temperatures cause rapid deterioration of the seed through formation of free fatty acids; hence the need for ventilation fans and aeration ducts when the temperature rises. At high moisture and temperatures of 28–37°C, cottonseed is also prone to invasion by the fungus, *Aspergillus flavus*, which produces aflatoxins (40). Aflatoxins are highly toxic and produce liver cancer in animals.

4.3. Peanuts. When the kernels are fully developed and taking on a mature color, the plants are dug mechanically, shaken to remove the soil, and inverted into windrows to dry (cure) and mature completely. Ideally, the peanuts are left to cure for several days until the moisture content drops to ca 10%. They are harvested mechanically. Green harvesting is practiced under adverse weather conditions, yielding peanuts with 18–25% moisture; artificial drying reduces the moisture to ca 10%. After the moisture is equilibrated between the kernels and hulls, the former contain 7–8% moisture, which is safe for storage.

The cured peanuts are stored or shelled and $<10\%$ of the crop is retailed in the shell. Shelled peanuts should have a moisture content of ca 7% (6.5% is optimum) for safe storage and are best stored under refrigeration. Moisture control is critical to maintain quality. At high moisture levels molds grow, including *Aspergillus flavus*, that produce aflatoxins. The Agricultural Marketing Service and the FDA limit aflatoxin to 25 ppb in raw peanuts and 20 ppb in processed peanut food products.

4.4. Sunflowers. Grown primarily in North Dakota, which is the principal producer, South Dakota, Minnesota, Kansas, Colorado, Texas, and Nebraska, sunflower seeds are harvested after a killing frost in late September and October, ca 120 d after planting. In rainy fall conditions, the seed may contain $>20\%$ moisture. Such seed must be dried rapidly to $\leq 10\%$ moisture. The crop dries easily because air readily passes through beds of the large seed. A moisture content of 9.5% is safe for short-term storage, but $\leq 7\%$ is recommended for long-term storage without aeration (41). Marketing channels lead from the farm to country elevators to processors and export terminals.

5. Processing

5.1. Soybeans. Virtually all soybeans processed in the United States are solvent-extracted with hexane to recover the oil. This traditional process is outlined in Figure 4. Beans arriving at the plant are cleaned and dried, if necessary, before storage. When the beans move from storage to processing, they are cleaned further and may be dried and allowed to equilibrate at 10−11% moisture to facilitate loosening of the seed coat or hull. They are then cracked, dehulled by screening and aspiration, and conditioned by treatment with steam to facilitate flaking. The conditioned meats are flaked and extracted with hexane to remove the oil. Hexane and the oil in the miscella are separated by evaporation and the hexane is recovered. Residual hexane in the flakes is removed by steam treatment in the desolventizer-toaster. The moist heat treatment also inactivates antinutritional factors, such as trypsin inhibitors and lectins, in the raw flakes and increases protein digestibility (42–44). Innovations in soybean processing include more efficient methods for dehulling (45) and the use of expanders (46,47). Expanders are extruders used to convert the flakes into collets, ie, porous, sponge-like extrudates. Collets are larger, denser, and less fragile than flakes and thus extract more rapidly and drain more completely, reducing the amount of hexane that needs to be recovered in the desolventizer. The result is to increase plant capacity. Fifty percent or more of the soybean plants use expanders, and adoption is expected to continue.

A metric ton of soybeans yields 181 kg of crude oil, 794 kg of 44% protein meal (hulls present), or 722 kg of 48% protein meal (hulls removed) plus 72 kg of hulls. Shrinkage is 25 kg.

5.2. Cottonseed. In the United States, cottonseed is processed into oil and meal by screw-pressing or solvent extraction. In screw-pressing the seed is cleaned, delinted, dehulled, flaked, and cooked prior to pressing. Screw-pressing yields a cake containing 2.5−4.0% residual oil. The cake is ground into a meal, and ground cottonseed hulls are blended back to adjust protein content to trading standards. In the solvent extraction procedure (Fig. 5) the flakes are often processed through an expander to rapidly cook the flakes and to form collets, which are then extracted with hexane (46,47). Meal emerging from the solvent extractors is freed of hexane by heating. The resulting meal contains about 1% residual oil.

Screw-pressed oil is allowed to stand to settle out suspended solids, filtered through plate filter presses, and then pumped to storage. The oil-rich solvent (miscella) from the solvent-extraction process is filtered or clarified, and most of the solvent is removed in a long tube evaporator. Finally, the concentrated oil passes through a stripping column where sparging steam is injected to remove the residual solvent. A metric ton of cottonseed yields ca 91 kg linters, 247 kg hulls, 162 kg oil, and 455 kg meal.

5.3. Peanuts. Only 15−20% of the U.S. peanut crop is converted into oil and meal. Processing is carried out by screw-pressing or prepressing, followed by solvent extraction (48). In screw-pressing, the peanuts are shelled, cooked, and pressed to yield a crude oil plus a cake containing ca 5% residual oil. The cake is ground, and the ground peanut hulls are blended back to adjust protein content. In prepressing−solvent extraction, the cooked meats are screw-pressed at low pressure to remove a portion of the oil and then extracted with hexane to reduce the residual oil to ca 1%. Residual hexane in the meal is recovered by applying jacket or live steam in a desolventizer. Hexane in the miscella is recovered by evaporation, as in the processing of cottonseed. A metric ton of peanuts yields ca 317 kg oil and 418 kg meal. The remainder is shells, foreign matter, and shrinkage.

5.4. Sunflowers. Processing of sunflowers consists of screw-pressing, direct extraction with hexane, or prepress–solvent extraction. The latter is most commonly used in the United States. The first step is cleaning, followed by dehulling. The dehulled seed is conditioned by heating and then goes to screw presses or is flaked as in the case of direct solvent extraction with hexane. The screw-pressed cake is ground for use in feeds or granulated and extracted by hexane to recover the remaining oil. In some plants the hulls are separated and burned to generate part of the power used in processing (49). On processing without dehulling, a metric ton of sunflower seed yields ca 400 kg of oil and 550 kg of high fiber meal.

6. Economic Aspects

In the U.S. soybeans were planted on 75.5×10^6 acres (30.6×10^6 hectares) in 2006, producing a record 3.188×10^9 bushels (86.77×10^6 metric tons) of soybeans. The average price paid to farmers was \$6.20 per bushel (\$228 per metric ton). The total 2006 crop value exceeded $\$19.7 \times 10^9$. See Table 7 for world production status (50).

In 2006, soybeans represented 57% of world oilseed production, and 38% of those soybeans were produced in the United States. The United States exported a record 1.1×10^9 bushels (29.9×10^6 metric tons) of soybeans, which accounted for 42% of the world's soybean trade. See Table 8 for world oilseed production and consumption (50).

U.S. soybean and product exports were $\$8.9 \times 10^9$ in 2006. China was the largest customer for U.S. soybeans with purchases totaling $\$2.5 \times 10^9$. Mexico was the second largest market for U.S. soybeans with purchases of $\$906 \times 10^6$. Other significant buyers included Japan with purchases of $\$863 \times 10^6$, and the European Union with purchases of $\$720 \times 10^6$.

Mexico was the largest customer for U.S. soybean meal at $\$377 \times 10^6$, Canada was second with purchases of $\$283 \times 10^6$, and The Philippines was third with purchases of $\$123 \times 10^6$. Mexico was the largest customer for U.S. soybean oil with purchases of $\$60 \times 10^6$, and China was second with purchases of $\$59 \times 10^6$.

In the U.S. soybeans provided 75% of the edible consumption of fats and oils in the United States. The domestic crush level was a record $1{,}780 \times 10^6$ bushels (48.4×10^6 metric tons), with U.S. ending stocks of soybeans at 595×10^6 bushels (16.2×10^6 metric tons). Table 9 gives world protein meal and vegetable oil consumption (50).

6.1. Long-term Projections. World soybean trade is projected to rise rapidly, climbing more than 27×10^6 metric tons (36%) during the next decade. Global trade in soybeans and soybean products has risen rapidly since the early 1990s, and has surpassed not only wheat, the traditional leader in agricultural commodity trade, but also total coarse grains (corn, barley, sorghum, rye, oats, millet, and mixed grains). Continued strong growth in global demand for vegetable oil and protein meal, particularly in China, is expected to maintain soybean and soybean-product trade well above wheat and coarse grains trade throughout the next decade (51).

Strong income and population growth in developing countries generates increasing demand for vegetable oils for food consumption and for protein meals used in livestock production. Additional demand is generated by the use of soybean oil in biodiesel production in some countries. World trade in soybeans and soybean oil both grow at an average annual rate of 3.5% through the projection period, compared with 2.7% for soybean meal. (51).

Long-term trade projections for soybeans, soybean meal, and soybean oil are listed in Tables 10–12.

7. Nutritional Properties and Antinutritional Factors

7.1. Oil. Because of their high linoleic acid [*60-33-3*] contents, unhydrogenated and partially hydrogenated soybean, cottonseed, peanut, and sunflower oils are good sources of this essential fatty acid. Soybean oil is the principal vegetable oil consumed in the United States, and approximately three-fourths is partially hydrogenated to improve flavor stability, increase resistance to oxidation, and increase the melting point. The last is important in margarines, bakery and confectionery fats, and shortenings. Linoleic and linolenic acid [*463-40-1*] contents of soybean oil are reduced by hydrogenation, but the process is also accompanied by migration of double bonds up and down the fatty acid chain and the conversion of cis to trans isomers, ie, positional and geometrical isomerization. Although epidemiological evidence has suggested a relationship between trans fatty acid consumption and coronary heart disease risk, a more recent review of the data concludes that such a conclusion is equivocal (52). Further study is needed to clarify the possible role of trans fatty acids in risk of heart disease. Interesterification of fats of different compositions is being used in Europe and Canada as an alternative to hydrogenation to modify the physical properties of oils. Interest in this process is increasing in the United States (53).

Heating of fats during the frying of foods results in hydrolysis and oxidation reactions that generate various compounds, including free fatty acids, alcohols, aldehydes, ketones, dimer acids, and polymeric fatty acids. Under extreme conditions of heating for prolonged periods of time, products toxic to laboratory animals can be formed. Foods produced in such situations are, however, unpalatable. Thus consumption of such foods becomes self-limiting (54).

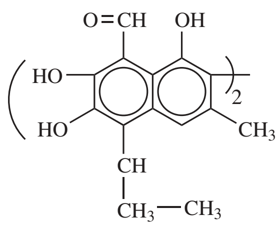
Cyclopropenoid fatty acids found in cottonseed oil are biologically active in several animal species (55). Upon ingestion by laying hens, these fatty acids are deposited in the egg yolks. On storage of the eggs, the yolks become rubbery and the whites turn pink (56). Cyclopropenoid acids act as synergists with aflatoxins and as liver carcinogens when fed to trout (57). The long history of cottonseed oil use in the human diet, however, has not revealed any adverse effects. Hence, there is presumptive evidence that humans are not affected at past and present levels of ingestion (58). Crude cottonseed oils contain 0.6–1.0% cyclopropenoid acids (59) but on refining, particularly during deodorization, the levels drop to 0.04–0.4% (60).

7.2. Proteins and Meals. Nutritional properties of the oilseed protein meals and their derived products are determined by the amino acid compositions, content of biologically active proteins, and various nonprotein constituents found in the defatted meals. Phytic acid (**3**), present as salts in all four meals, is believed to interfere with dietary absorption of minerals such as zinc, calcium, and iron (61).

Soybeans. Numerous studies have demonstrated that methionine is the first limiting amino acid in soybean proteins. That is, methionine is in greatest deficit for meeting the nutritional requirements of a given species. Although it is common practice to add synthetic methionine to broiler feeds to compensate for this deficiency, methionine supplementation is not necessary for humans except for infants (62). Table 3 shows that soybean proteins meet or exceed the essential amino acid requirements of FAO/WHO/UNU for children from age 2 to adults. The presence of trypsin inhibitors in soybeans is well-documented, and when ingested by laboratory animals, these inhibit growth and affect organs such as the pancreas (42,43). The inhibitors are largely inactivated by moist heat, and there are no documented cases where ingestion of soybeans by humans has affected the pancreas.

Cottonseed. When compared with FAO/WHO/UNU essential amino acid requirements (see Table 3), cottonseed proteins are low in lysine, threonine, and leucine for 2 to 5-year-old children, yet meet all requirements for adults.

Raw defatted cottonseed flours contain 1.2–2.0% gossypol [*303-45-7*] (**7**) (19). When cottonseed is treated with moist heat, the ϵ-amino group of lysine and gossypol forms a derivative that is biologically unavailable thereby inactivating gossypol but further lowering the effective content of lysine.



(**7**)

Gossypol has other adverse effects. It is toxic to monogastric animals and, when present in rations of laying hens, causes yolk discoloration (4,56). Ruminants are generally considered to be capable of detoxifying gossypol, but when large quantities of gossypol are ingested for several weeks, toxicosis can occur (63). Cottonseed flour containing gossypol has been fed to humans in a number of studies, but no instances of toxicity have been reported (4). The U.S. Food and Drug Administration (FDA) limits the content of free gossypol, the portion extractable with acetone:water, 70:30 (vol/vol), in edible cottonseed flour to 450 ppm. Gossypol content of cottonseed flour can be lowered by liquid or air classification to remove the pigment glands but neither method is used commercially (5). Glandless gossypol-free cottonseed was formerly produced on a limited scale.

The cyclopropenoid fatty acids, malvalic acid and sterculic acid, exist in hexane-defatted meal at levels of 21–76 ppm (64). In rainbow trout, the cyclopropenoid acids cause cancer of the liver either alone or by acting synergistically with aflatoxin B_1. However, similar effects in mammals or humans have not been demonstrated (57).

Contamination of cottonseed by aflatoxins is a perennial concern. The FDA limits the amount of aflatoxin in cottonseed meal intended for beef cattle, swine, and poultry to 300 ppb and for dairy cattle the limit is 20 ppb.

Peanuts. The proteins of peanuts are low in lysine, threonine, cystine plus methionine, and tryptophan when compared to the amino acid requirements for children but meet the requirements for adults (see Table 3). Peanut flour can be used to increase the nutritive value of cereals such as cornmeal but further improvement is noted by the addition of lysine (65). The trypsin inhibitor content of raw peanuts is about one-fifth that of raw soybeans, but this concentration is sufficient to cause hypertrophy (enlargement) of the pancreas in rats. The inhibitors of peanuts are largely inactivated by moist heat treatment (48). As for cottonseed, peanuts are prone to contamination by aflatoxin. FDA regulations limit aflatoxin levels of peanuts and meals to 100 ppb for breeding beef cattle, breeding swine, or poultry; 200 ppb for finishing swine; 300 ppb for finishing beef cattle; 20 ppb for immature animals and dairy animals; and 20 ppb for humans.

Sunflower Seed. Compared to the FAO/WHO/UNU recommendations for essential amino acids, sunflower proteins are low in lysine, leucine, and threonine for two to five-year-olds but meet all the requirements for adults (see Table 3). There are no principal antinutritional factors known to exist in raw sunflower seed (35). However, moist heat treatment increases the growth rate of rats, thereby suggesting the presence of heat-sensitive material responsible for growth inhibitions in raw meal (66). Oxidation of chlorogenic acid may involve reaction with the ϵ-amino group of lysine, thus further reducing the amount of available lysine.

8. Oilseed Products and Uses

8.1. Oil. Most crude oil obtained from oilseeds is processed further and converted into edible products. Only a small fraction of the total oil from soybeans, cottonseed, peanuts, and sunflower seed is used for industrial (nonedible) purposes.

Edible Oil. For edible uses, oilseed oils are processed into salad and cooking oils, shortenings, margarines, and confectionery fats such as for candy, toppings, icings, and coatings (67). These products are prepared by a series of steps, as outlined for soybean oil in Figure 6. Uses for soybean oil are given in Table 13.

Degumming removes the phosphatides and gums, which are refined into commercial lecithin or returned to the defatted flakes just before the desolventizing-toasting step (see Fig. 4, hexane extraction). Then, free fatty acids, color bodies, and metallic prooxidants are removed using aqueous alkali. Some processors omit the water-degumming step and remove the phosphatides and free fatty acids with alkali in a single operation. High vacuum steam distillation in the deodorization step removes undesirable flavors to yield a product suited for salad oil. Partial hydrogenation, under conditions where linolenate is selectively hydrogenated, results in greater stability to oxidation and flavor deterioration. After winterization, ie, cooling and removal of solids that crystallize in the cold, the product is suited for use as salad and cooking oils. Alternatively, soybean oil can be hydrogenated under selective or nonselective conditions to increase its melting point and produce hardened fats. Such a partially hydrogenated soybean oil, by itself or in a blend with other vegetable oils or animal fats, is used for shortening and margarine. Blends of soybean or other oils of varying melting point ranges are utilized to obtain desired physical characteristics, eg, mouth feel and plastic melting ranges, and the least expensive formulation.

Polyunsaturated fatty acids in vegetable oils, particularly linolenic esters in soybean oil, are especially sensitive to oxidation. Even a slight degree of oxidation, commonly referred to as flavor reversion, results in undesirable flavors, eg, beany, grassy, painty, or fishy. Oxidation is controlled by the exclusion of metal contaminants, eg, iron and copper; addition of metal inactivators such as citric acid; minimum exposure to air, protection from light, and selective hydrogenation to decrease the linolenate content to ca 3% (68). Careful quality control is essential for the production of acceptable edible soybean oil products (69).

8.2. Protein Products. The bulk of the meal obtained in processing of oilseeds is used as protein supplements in animal feeds. Since the 1960s appreciable amounts have been also converted into products for human consumption, the majority of which have been derived from defatted soybean flakes.

Feeds. The high protein content of oilseed meals has made them essential ingredients of poultry and livestock feeds. Approximate compositions are shown in Table 14. Soybean meal, especially the dehulled product, is low in crude fiber and high in lysine. Although limiting in methionine, soybean meal is a key ingredient for blending with corn in formulating feeds for nonruminants, eg, poultry and swine. The two proteins complement each other; soy supplies the lysine and corn provides some of the methionine. Poultry rations are routinely supplemented with synthetic methionine to provide a balanced ration at relatively low cost. Because of its gossypol content, high fiber, and low lysine content, cottonseed meal is used primarily for beef and dairy feeds. Less than one-third of the U.S. cottonseed meal is used for poultry feeds. Peanut meal also is high in fiber but limiting in lysine and methionine, and low in tryptophan; its main outlet is therefore for dairy and beef cattle feeds. Sunflower meal is high in fiber and low in lysine and threonine, and therefore also fed mainly to ruminants, ie, sheep, beef, and dairy cattle. It is sometimes used to partially replace soybean meal in poultry and swine rations.

Edible Protein Ingredients. As of the mid-1990s only peanuts and soybeans are converted into protein ingredients for use in food products. Peanuts are hydraulically pressed to remove about 55% of the oil and the pressed peanuts are then ground into flours and sold raw or roasted for use in baked products, snacks, and confections.

Starting materials for soybean protein ingredients are defatted flakes prepared essentially as outlined in Figure 4, except that greater attention is paid to sanitation than in processing for feed use, and the hexane is removed by vapor desolventizing–deodorizing or flash desolventizing, thereby yielding flakes ranging from raw to fully cooked (72). Degree of cooking is determined by measuring the amount of water-soluble protein remaining after moist heat treatment with the protein dispersibility index (PDI) or nitrogen solubility index (NSI) test (73).

A raw flake has a PDI or NSI of ca 90, whereas a fully cooked flake has a value of 5–15.

Defatted soybean flakes are processed into three classes of products differing in minimum protein content (expressed on a dry basis): flours and grits (50% protein); protein concentrates (65% protein); and protein isolates (90% protein). Table 15 shows typical analyses. Flours and grits are made by grinding and sieving flakes. Concentrates are prepared by extracting and removing the soluble sugars from defatted flakes by leaching with dilute acid at pH 4.5 or by leaching with aqueous alcohol (75). Protein isolates are obtained by extracting the soluble proteins from defatted flakes with water at pH 8–9, precipitating with acid at pH 4.5, centrifuging the resulting protein curd, washing, redispersing in water (with or without adjusting the pH to ca 7), and finally spray-drying (76,77). Flours, concentrates, and isolates are also processed, commonly by extrusion, to texturize them for use as meat extenders and substitutes (78).

Oilseed proteins are used as food ingredients at concentrations of 1–2% to nearly 100%. At low concentrations, the proteins are added primarily for their functional properties, eg, emulsification, fat absorption, water absorption, texture, dough formation, adhesion, cohesion, elasticity, film formation, and aeration (79). Because of high protein contents, textured flours and concentrates are used as the principal ingredients of some meat substitutes.

Use of some oilseed proteins in foods is limited by flavor, color, and flatus effects. Raw soybeans, for example, taste grassy, beany, and bitter. Even after processing, residues of these flavors may limit the amounts of soybean proteins that can be added to a given food (80). The use of cottonseed and sunflower seed flours is restricted by the color imparted by gossypol and phenolic acids, respectively. Flatus production by defatted soy flours has been attributed to raffinose and stachyose, which are removed by processing the flours into concentrates and isolates (81).

8.3. Food Products. Soybeans, peanuts, and sunflower seeds are consumed as such or are processed into edible products.

Soybeans. Soybeans are not eaten raw because they are too hard and have an unpalatable grassy–beany flavor. Small amounts are roasted and salted for snacks. Nut substitutes for baked products and confections are also manufactured from soybeans. Larger amounts are used in Oriental foods, some of which are increasingly popular in the United States.

Soymilk. In the traditional process, soybeans are soaked in water, ground into a slurry, cooked, and filtered to remove the insoluble cell wall and hull fractions. A number of modifications have been made in the process since the 1960s, including heat treatment before or during grinding to inactivate the enzyme lipoxygenase and thus prevent formation of grassy and beany flavors. The soymilks are available in plain and flavored, eg, vanilla and chocolate, forms (82,83).

Tofu. Tofu is prepared by adding a coagulant such as calcium sulfate to soymilk to precipitate the protein and oil into a gelatinous curd. The curd is then separated from the soluble portion (whey), pressed, and washed to yield a market-ready product. Tofu, a traditional food in Japan (82), was popularized in the United States in the late 1970s and is available in many U.S. supermarkets.

Miso. Miso is a paste-like food having the consistency of peanut butter. It is made by fermenting cooked soybeans and salt with or without a cereal such as rice or barley (84). It is used as a base for soups in Japan, and as a seasoning in southern and eastern Asia. It is produced on a small scale in the United States.

Tempeh. Dehulled cooked soybeans are inoculated with the mold, *Rhizopus oligosporus*, packed in perforated plastic bags, and allowed to ferment for 18 h. The mold mycelium overgrows the soybean cotyledons and forms a compact cake. When sliced and deep-fried in oil, a crisp and golden brown product is obtained. Although native to Indonesia, tempeh has become popular with vegetarians in the United States and other Western countries (85).

Soy Sauce. Soy sauce is a well-known condiment made by fermentation or acid hydrolysis. In the fermentation process defatted soybean meal is cooked and then mixed with roasted, coarsely ground wheat and mixed with a culture of *Aspergillus oryzae* or *Aspergillus sojae*. After the mold grows for 2–3 d to form koji, brine is added, and the mixture is allowed to ferment for 6–8 m. The product is then filtered and pasteurized (86). Popularization of fermented soy sauce in the U.S. began in the late 1940s with imports from Japan, followed by construction of a plant in Wisconsin in 1973. Soy sauce is widely available in U.S. supermarkets and restaurants. In the acid hydrolysis process, defatted soybean flour is refluxed with hydrochloric acid to hydrolyze the proteins. The hydrolysate is then filtered, neutralized, and bottled.

Peanuts. About 65% of U.S. peanuts are consumed directly in the form of peanut butter, roasted peanuts, and confections. Peanut butter is made and consumed primarily in the United States. It is prepared by shelling the nuts, dry roasting, removing the skins, and grinding finely. The ground material is then blended with salt and other ingredients that may include stabilizers, eg, vegetable oil, mono- and diglycerides; sweeteners, eg, glucose, corn syrup solids, or honey; lecithin; and antioxidants (87).

Sunflower Seed. Confectionery-type sunflower seed, ca 15% of the U.S. crop, is cleaned and sized by screening. The large seed is dry-roasted, salted, and sold in the shell. The medium sized seeds are dehulled, roasted dry or in oil and used in cookies, salad toppings, ice cream toppings, trail and snack mixes, and breads and rolls. The small-sized, off-sized, and broken seed is sold as bird and pet feeds (88).

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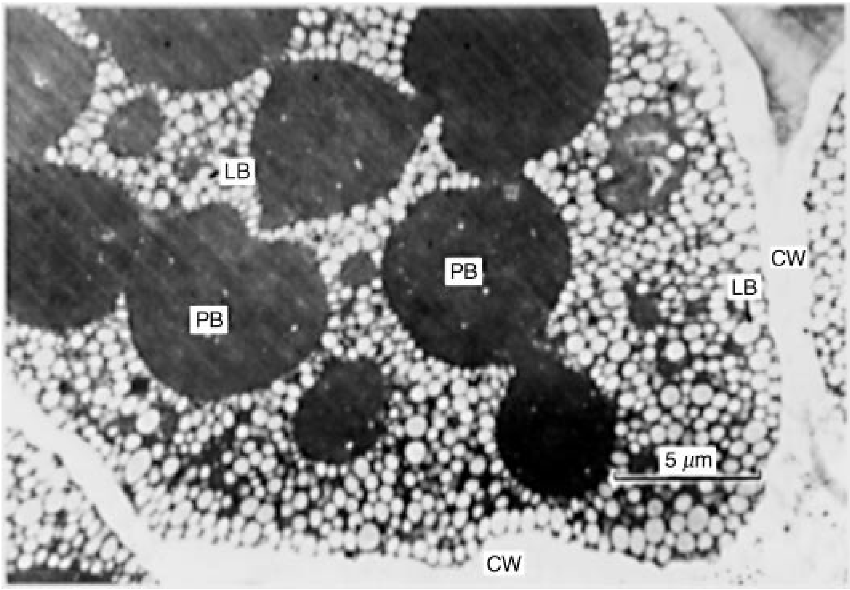

Fig. 1. Transmission electron micrograph of a section of a mature, hydrated soybean cotyledon. Protein bodies (PB), lipid bodies (LB), and cell wall (CW) are identified (2).

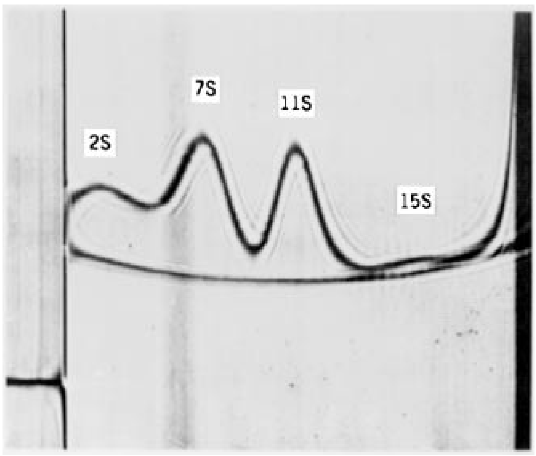

Fig. 2. Ultracentrifugal pattern for the water-extractable proteins of defatted soybean meal in pH 7.6, 0.5 ionic strength buffer. Numbers above peaks are approximate sedimentation coefficients in Svedberg units, S. Molecular weight ranges for the fractions are 2S, 8,000–50,000; 7S, 100,000–180,000; 11S, 300,000–350,000; and 15S, 600,000–700,000 (9). The 15S fraction is a dimer of the 11S protein (10).

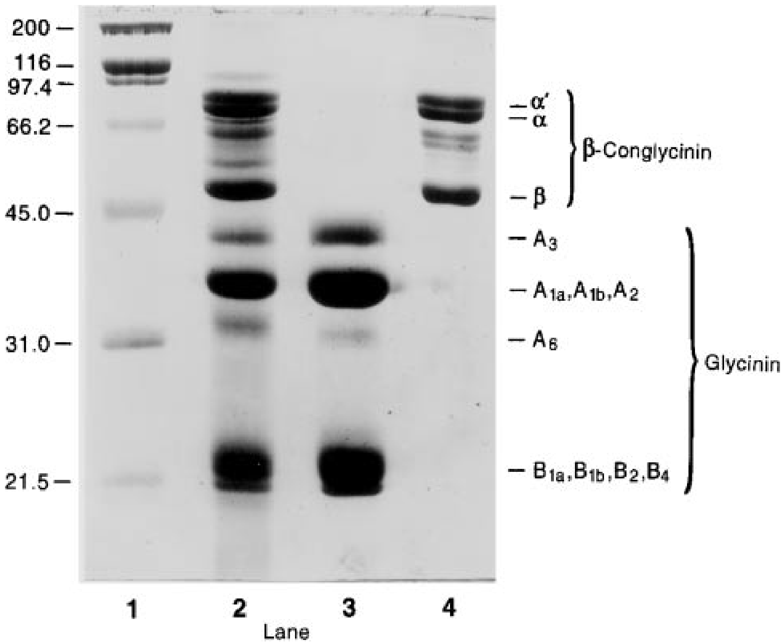

Fig. 3. Sodium dodecyl sulfate–polyacrylamide gel electrophoretic pattern for molecular weight standards (lane 1); water-extractable proteins of defatted soybean meal (lane 2); purified 11S (glycinin) (lane 3); and purified 7S (β-conglycinin) (lane 4) where the numbers represent mol wt $\times 10^3$. The gel was run in the presence of 2-mercaptoethanol, resulting in the cleavage of the disulfide bond linking the acidic (A bands) and basic (B bands) polypeptides of the 11S molecule.

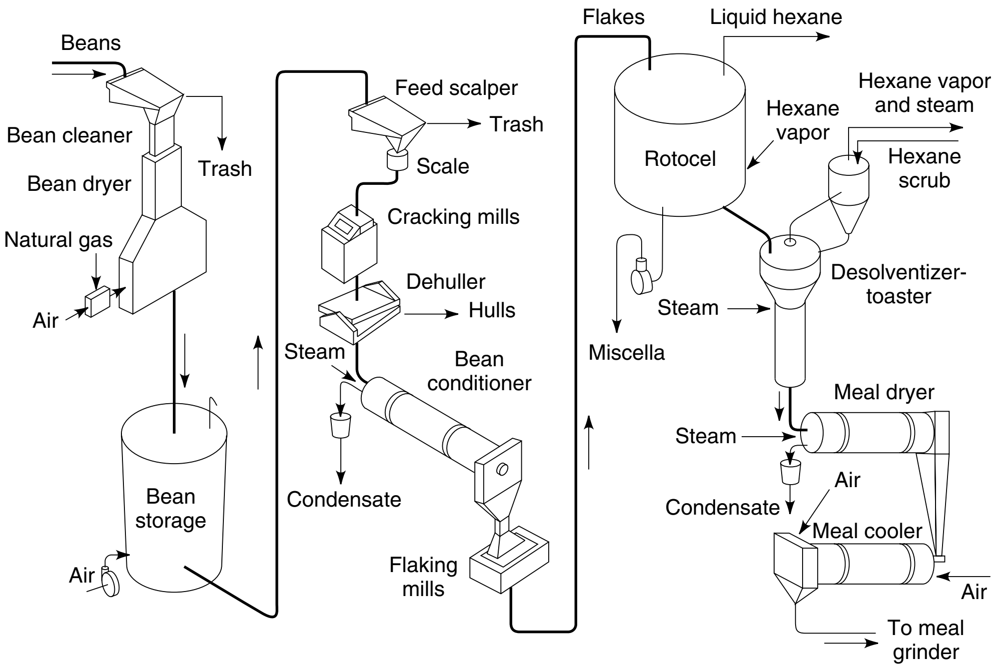

Fig. 4. Schematic outline for processing soybeans into oil and meal by hexane extraction. Courtesy of Dravo Corporation.

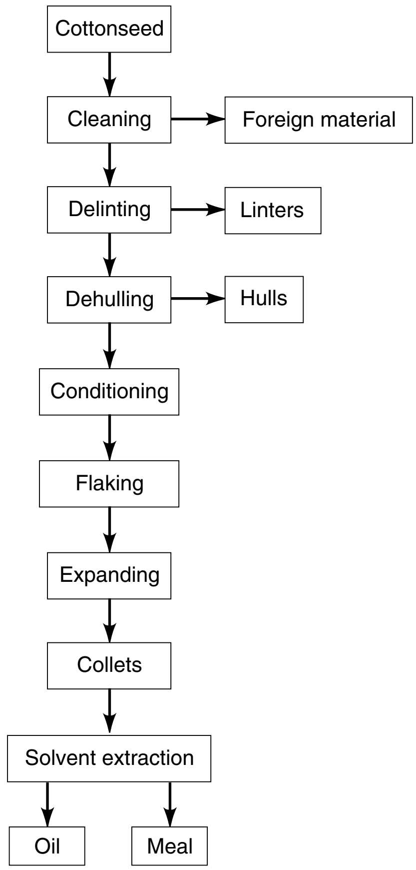

Fig. 5. Schematic outline for processing of cottonseed into oil and meal.

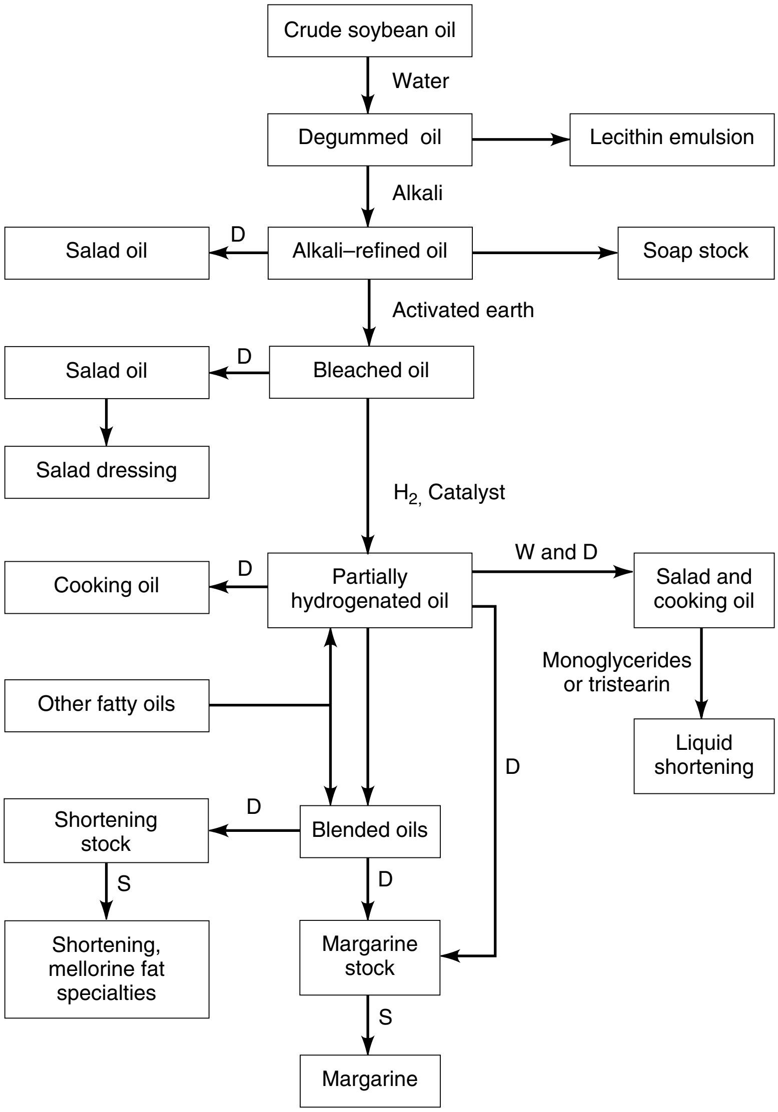

Fig. 6. Schematic outline for manufacture of edible soybean oil products, where D = deodorization W = winterization, and S = solidification (67). Courtesy of the American Soybean Association and the American Oil Chemists' Society.

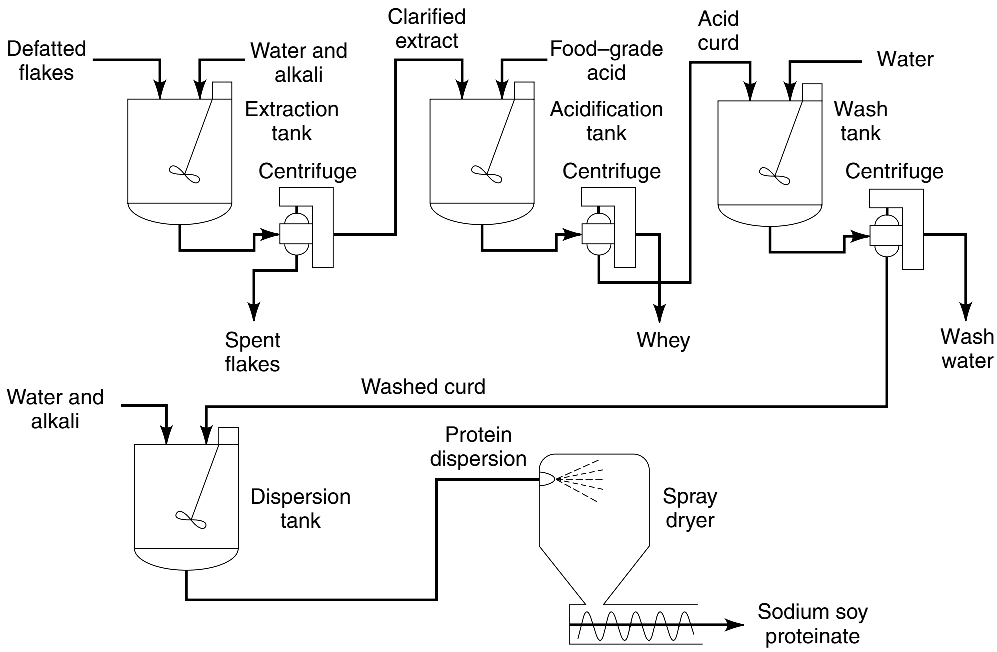

Fig. 7. Schematic outline for manufacture of soybean protein isolates.

Table 1. **Botanical Classification, Area of Production, and Uses of Oilseeds**

Botanical classification		Principal production areas	Uses
Family	Genus and species		
		Soybean	
Leguminosae (legume)	*Glycine max Merrill*	United States, Brazil, People's Republic of China, Argentina	edible oil, animal feed, food, edible proteins, industrial oils and proteins
		Cottonseed	
Malvaceae (mallow)	*Gossypium arboreum*, Sri Lanka cotton; *G. herbaceum*, Levant cotton; *G. barbadense*, Sea Island cotton; *G. hirsutum*, Upland cotton	People's Republic of China, United States, India, FSU[a]	edible oil, animal feed
		Peanut	
Leguminosae (legume)	*Arachis hypogaea*	People's Republic of China, India, United States	food, edible oil, animal feed, edible protein
		Sunflower	
Compositae (composite)	*Helianthus annuus*	Argentina, FSU[a], European Union, United States	edible oil, animal feed, food

[a]Former Soviet Union.

Table 2. **Composition[a] of Oilseeds, Wt %[b]**

Oilseed	Hulls	Oil	Protein[c]	Ash	Protein in dehulled, defatted meal[d]
soybean	8	20	43	5.0	52
cottonseed					
acid delinted	36	21.6	21.5	4.2	
kernels		36.4	32.5	4.7	63
peanut	20–30				
kernels	2–3.5[e]	50.0	30.3	3.0	57
sunflower					
arrowhead variety, low oil type[f]	47	29.8	18.1		~68[g]
armavirec variety					~60[g]
high oil type[f]	30	48.0	16.9		
kernels[f]		64.7	21.2		

[a]Approximate; moisture-free basis.
[b]Ref. 6, except as otherwise noted.
[c]As nitrogen, N, × 6.25.
[d]Data vary with efficiency of dehulling and oil extraction, variety of seed, and climatic conditions during growth.
[e]Red skins or testa.
[f]Ref. 7.
[g]Calculated from kernels on oil-free basis.

Table 3. **Amino Acid Composition of Defatted Oilseed Meals and Amino Acid Requirements, mg/g Crude Protein**

					Requirements[e]		
					Child, age		
Amino acid	Soybean[a]	Cottonseed[b]	Peanut[c]	Sunflower[d]	2–5	10–12	Adult
lysine	64	44	30	38	58	44	16
histidine	26	27	23	25	19	19	16
arginine	73	116	113	89			
aspartic acid	118	92	141	87			
threonine	39	30	25	32	34	28	9
serine	55	42	49	39			
glutamic acid	186	217	199	210			
proline	55	36	44	50			
glycine	43	41	56	51			
alanine	43	39	42	41			
valine	46	45	45	48	35	25	13
cystine	14	26	13	18 }	25	22	17
methionine	11	15	9	19 }			
isoleucine	46	31	41	40	28	28	13
leucine	78	58	67	61	66	44	19
tryosine	38	31	41	27 }	63	22	19
phenylalanine	50	54	52	47 }			
tryptophan	14	12	10	11	11	9	5

[a]Means based on 32 hydrolysates except for proline, cystine, and tryptophan (18).
[b]Means for eight-glanded seed varieties (19).
[c]Ref. 20.
[d]Means for seven varieties (7).
[e]Essential amino acid requirements for humans recommended by FAO/WHO/UNU (21). An essential amino acid is one that cannot be synthesized by humans at a sufficiently rapid rate to meet metabolic needs.

Table 4. **Fatty Acid Composition of Unprocessed Oilseed Oils, Wt %**

Carboxylic acid[a]	Soybean[b]	Cottonseed[b]	Peanut[c]	Sunflower[b]
		Saturated fatty acids		
10:0		0.48		
12:0	0.10	0.38		
14:0	0.16	0.79		0.1
16:0	10.7	22.0	10.5	5.81
18:0	3.87	2.24	3.2	4.11
20:0	0.22	0.19	1.4	0.29
22:0			2.1	
24:0			0.7	
		Unsaturated fatty acids		
16:1	0.29	0.78		0.10
18:1	22.8	18.1	50.3	20.7
18:2	50.8	50.3	30.6	63.5
18:3	6.76	0.40		0.32
20:1			1.0	0.10

[a]Carboxylic acid nomenclature designates number of carbons:number of double bonds. For example, 10:0 indicates a fully saturated C_{10} acid.
[b]Ref. 22.
[c]Mean values for 1968 crop of 82 peanut genotypes (23).

Table 5. **Composition of Oilseed Sterols[a], %**

Oil CAS Registry Number	Campesterol[b] [*474-62-4*]	Stigmasterol[c] [*83-48-7*]	β-Sitosterol[d] [*83-46-5*]	Δ^5-Avenasterol[e]	Δ^7-Stigmasterol [*83-45-4*]
soybean	20	20	53	3	3
cottonseed	4	1	93	2	trace
peanut	15	9	64	8	3
sunflower	8	8	60	4	15

[a]Ref. 26.
[b]Also known as ergost-5-en-3-ol (**1**).
[c]Stigmasterol is stigmasta-5,22-dien-3β-ol.
[d]Also known as stigmasta-5-en-3-ol (**2**).
[e]Δ^5-avenasterol is stigmasta-5,24(28)-dien-3β-ol.

Table 6. **Oligosaccharide Contents of Defatted Oilseed Meals[a], %**

Constituent	Soybean	Cottonseed	Peanut	Sunflower
sucrose	6.42	1.64	8.1	6.5
raffinose	1.26	6.91	0.33	3.09
stachyose	4.34	2.36	0.99	0.14
verbascose	trace	trace	trace	
Total	*12.02*	*10.91*	*9.42*	*9.73*
Total carbohydrate[b]	*34.0*	*22.5*	*22.4*	*24.2*

[a]Ref. 28.
[b]Ref. 29. Estimated by difference: 100 − (protein + oil + ash + crude fiber) = nitrogen-nitrogen-free extract.

Table 7. **World Soybean Production, 2006[a]**

Country	Production, 10^6 t
United States	86.8
Brazil	56.0
Argentina	44.0
China	16.2
India	7.3
Paraguay	4.7
Canada	3.5
other	9.9
Total	*228.4*

[a]Ref. 50.

Table 8. **World Oilseed Production and Consumption, 2006**[a]

Oilseed	Production, 10^6 t	Consumption, 10^6 t
soybean	228.4	151.3
rapeseed	46.6	27.4
cotton	43.7	14.9
peanut	31.7	5.7
sunflower	30.8	11.5
palm	10.9	5.5
copra	5.2	1.7
Total	*397.3*	*218*

[a]Ref. 50.

Table 9. **World Protein Meal and Vegetable Oil Consumption, 2006**[a]

Type	Protein meal, 10^6 t	Vegetable oil 10^6 t
soybean	151.3	35.7
palm		38.1
rapeseed	27.4	17.8
cotton	14.9	4.8
sunflower	11.5	10.2
peanut	5.7	4.9
fish	5.5	
palm kernel	5.5	4.3
copra	1.7	
coconut		3.3
olive		2.9
Total	*223.5*	*122*

[a]Ref. 50.

Table 10. **Soybean Trade Long-term Projections**[a]

	2005/06	2006/07	2007/08	2008/09	2009/10	2010/11	2011/12	2012/13	2013/14	2014/15	2015/16	2016/17
					Imports, $\times 10^6$ t							
Importers												
European Union[b]	13.8	14.1	13.5	13.6	13.5	13.4	13.2	13.1	13.0	12.9	12.6	12.4
Japan	4.0	4.1	4.1	4.1	4.1	4.1	4.2	4.2	4.2	4.2	4.2	4.2
South Korea	1.2	1.3	1.3	1.2	1.2	1.2	1.2	1.2	1.1	1.1	1.1	1.1
Taiwan	2.4	2.4	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Mexico	3.7	3.8	3.9	4.0	4.1	4.2	4.3	4.5	4.6	4.7	4.8	4.9
Former Soviet Union[c]	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2
Other Europe	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.7
China	28.3	32.0	35.9	38.4	40.9	43.8	46.5	48.7	50.8	52.9	55.1	57.2
Malaysia	0.5	0.6	0.6	0.6	0.7	0.7	0.7	0.8	0.8	0.8	0.9	0.9
Indonesia	1.3	1.4	1.4	1.5	1.6	1.6	1.7	1.7	1.8	1.8	1.9	1.9
other	8.7	10.3	10.9	11.4	12.0	12.6	13.1	13.7	14.3	14.9	15.4	16.0
Total imports	*64.4*	*70.6*	*74.8*	*78.2*	*81.3*	*84.8*	*88.2*	*91.1*	*93.9*	*96.7*	*99.4*	*102.0*
					Exports, $\times 10^6$ t							
Exporters												
Argentina	7.3	7.0	6.5	6.5	6.5	6.4	6.4	6.3	6.3	6.2	6.2	6.1
Brazil	25.9	25.9	29.9	37.4	44.4	47.6	50.5	53.1	55.3	57.7	59.7	62.0
other South America	3.3	4.1	4.3	4.5	4.8	5.0	5.3	5.5	5.8	6.1	6.4	6.7
China	0.3	0.4	0.4	0.4	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.3
other foreign	1.8	2.1	2.4	2.2	2.3	2.4	2.5	2.7	2.8	2.9	3.1	3.3
United States	25.8	31.2	31.3	27.2	23.0	23.0	23.1	23.1	23.4	23.4	23.7	23.7
Total exports	*64.4*	*70.6*	*74.8*	*78.2*	*81.3*	*84.8*	*88.2*	*91.1*	*93.9*	*96.7*	*99.4*	*102.0*
U.S. trade share, %	40.0	44.2	41.9	34.8	28.3	27.1	26.2	25.4	24.9	24.2	23.8	23.2

[a] Ref. 51, The projections were completed in November 2006.
[b] Covers EU-25, excludes intra-EU trade.
[c] Covers FSU-12, includes intra-FSU trade.

Table 11. **Soybean Meal Trade Long-term Projections**[a]

	2005/06	2006/07	2007/08	2008/09	2009/10	2010/11	2011/12	2012/13	2013/14	2014/15	2015/16	2016/17
					Imports, $\times 10^6$ t							
Importers												
European Union[b]	22.9	22.7	22.9	23.3	23.6	23.9	24.2	24.5	24.8	25.1	25.4	25.7
former Soviet Union[c]	0.7	0.7	0.7	0.8	0.9	1.0	1.0	1.1	1.2	1.2	1.3	1.4
other Europe	0.7	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.9	0.9	0.9	0.9
Canada	1.3	1.4	1.4	1.4	1.5	1.5	1.6	1.6	1.7	1.8	1.8	1.9
Japan	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.7	1.7	1.7	1.7
Southeast Asia	8.0	8.5	8.8	9.2	9.5	9.9	10.2	10.5	10.9	11.3	11.6	12.0
Latin America	7.0	7.4	7.7	8.0	8.4	8.7	9.0	9.3	9.7	10.0	10.3	10.6
North Africa and Middle East	4.0	4.8	5.1	5.4	5.8	6.1	6.4	6.7	7.0	7.3	7.7	8.0
other	5.1	5.2	5.4	5.6	6.0	6.2	6.4	6.6	86.8	6.9	7.0	7.2
Total imports	*51.3*	*52.9*	*54.5*	*56.2*	*57.9*	*59.6*	*61.2*	*62.9*	*64.5*	*66.1*	*67.7*	*69.4*
					Exports, $\times 10^6$ t							
Exporters												
Argentina	24.3	26.3	27.6	28.2	29.3	30.4	31.2	32.0	32.8	33.5	34.1	34.7
Brazil	12.9	12.6	12.9	13.1	13.8	14.2	14.8	15.7	16.4	17.2	18.2	19.3
other South America	1.6	1.7	1.8	1.8	1.8	1.9	1.9	2.0	2.0	2.0	2.1	2.1
China	0.4	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
India	3.7	3.0	2.8	2.8	2.7	2.7	2.6	2.6	2.5	2.5	2.5	2.4
European Union[b]	0.7	0.8	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
other foreign	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
United States	7.2	7.7	8.2	9.0	9.2	9.3	9.5	9.5	9.5	9.6	9.6	9.7
Total exports	*51.3*	*52.9*	*54.5*	*56.2*	*57.9*	*59.6*	*61.2*	*62.9*	*64.5*	*66.1*	*67.7*	*69.4*
U.S. trade share, %	14.1	14.6	15.0	16.1	15.8	15.5	15.5	15.1	14.8	14.5	14.2	14.0

[a]Ref. 51, The projections were completed in November 2006.
[b]Covers EU-25, excludes intra-EU trade.
[c]Covers FSU-12, includes intra-FSU trade.

Table 12. **Soybean Oil Trade Long-term Projections**[a]

	2005/06	2006/07	2007/08	2008/09	2009/10	2010/11	2011/12	2012/13	2013/14	2014/15	2015/16	2016/17
					Imports, $\times 10^6$ t							
Importers												
China	1.5	1.7	1.6	1.7	1.7	1.8	1.8	1.9	2.1	2.2	2.3	2.4
India	1.7	1.9	1.8	1.7	1.7	1.8	1.8	1.9	1.9	2.0	2.0	2.1
other Asia	0.9	1.0	1.0	1.0	1.0	1.1	1.1	1.1	1.2	1.2	1.2	1.3
Latin America	1.4	1.4	1.4	1.5	1.6	1.6	1.6	1.7	1.7	1.7	1.7	1.8
North Africa and Middle East	2.0	2.0	2.1	2.1	2.2	2.2	2.3	2.3	2.4	2.5	2.5	2.6
European Union[b]	0.7	0.9	0.9	1.0	1.0	1.2	1.4	1.5	1.7	1.8	2.0	2.1
former Soviet Union and other Europe[c]	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.2
other	1.0	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.1	1.1	1.1	1.1
Total imports	*9.3*	*9.9*	*9.9*	*10.0*	*10.3*	*10.8*	*11.2*	*11.7*	*12.2*	*12.6*	*13.0*	*13.5*
					Exports, $\times 10^6$ t							
Exporters												
Argentina	5.6	5.9	6.0	6.2	6.4	6.7	6.9	7.1	7.3	7.4	7.6	7.7
Brazil	2.1	2.3	2.2	2.2	2.3	2.5	2.7	3.0	3.3	3.5	3.8	4.1
European Union[b]	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
other foreign	0.9	1.0	1.0	1.0	1.0	1.0	1.1	1.1	1.1	1.1	1.1	1.1
United States	0.5	0.6	0.4	0.4	0.3	0.3	0.4	0.4	0.4	0.4	0.3	0.3
Total exports	*9.3*	*9.9*	*9.9*	*10.0*	*10.3*	*10.8*	*11.2*	*11.7*	*12.2*	*12.6*	*13.0*	*13.5*
U.S. trade share, %	5.6	5.7	4.5	4.0	3.1	2.9	3.1	3.0	2.9	2.8	2.6	2.4

[a]Ref. 51, The projections were completed in November 2006.
[b]Covers EU-25, excludes intra-EU trade.
[c]Includes intra-FSU trade.

Table 13. **Uses for Soybean Oil, 2006**[a]

Use	10^6 t
salad or cooking	4.22
baking and frying	3.00
margaine	0.44
industrial	1.08
other edible	0.06

[a]Ref. 50.

Table 14. **Compositions of Oilseed Protein Meals**[a,b]**, wt %**

		Crude			
Meal	Dry matter	Protein	Fat	Fiber	Ash
		Solvent process			
soybean					
with hulls	89.6	44.0	0.5	7.0	6.0
dehulled	89.3	47.5	0.5	3.0	6.0
peanut with hulls	92.3	47.0	1.0	13.0	4.8
		Prepress-solvent process			
cottonseed	89.9	41.0	0.8	12.7	6.4
sunflower[c]	89.4	31.0	2.5	21.8	6.0

[a]Ref. 70, unless otherwise noted.
[b]Analytical values, on an as-is basis, are approximate.
[c]Ref. 71.

Table 15. **Compositions of Soybean Protein Products and Their Uses[a], wt %**

Constituent	Defatted flours and grits[b]	Protein	
		Concentrates[c]	Isolates[d]
protein[e]	56.0	72.0	96.0
fat	1.0	1.0	0.1
fiber	3.5	4.5	0.1
ash	6.0	5.0	3.5
carbohydrates			
soluble	14.0	2.5	0
insoluble	19.5	15.0	0.3

[a]Analytical values on a moisture-free basis (74).
[b]Used in baked goods (breads, cakes, cookies, crackers, doughnuts), pasta products, emulsified and coarsely ground meat products, meat analogues, breakfast cereals, dietary foods, infant foods, confections, milk replacers, and pet foods.
[c]Used in baked goods (breads, cakes, cookies, snack items), pasta products, infant formulas, milk replacers, emulsified and coarsely ground meat items, meat analogues, dietary foods, and soup mixes and gravies.
[d]Used in baked goods (breads, cakes and cake mixes, cookies, crackers, snacks), pasta products, dairy-type products (beverage powders, coffee whiteners, whipped toppings), infant formulas, milk replacers for young animals, emulsified and coarsely ground meat items, meat analogues, hams, poultry breasts, dietary food items, and soup mixes and gravies.
[e]As nitrogen, N, $\times$ 6.25.