The case for food-grade soybean varieties

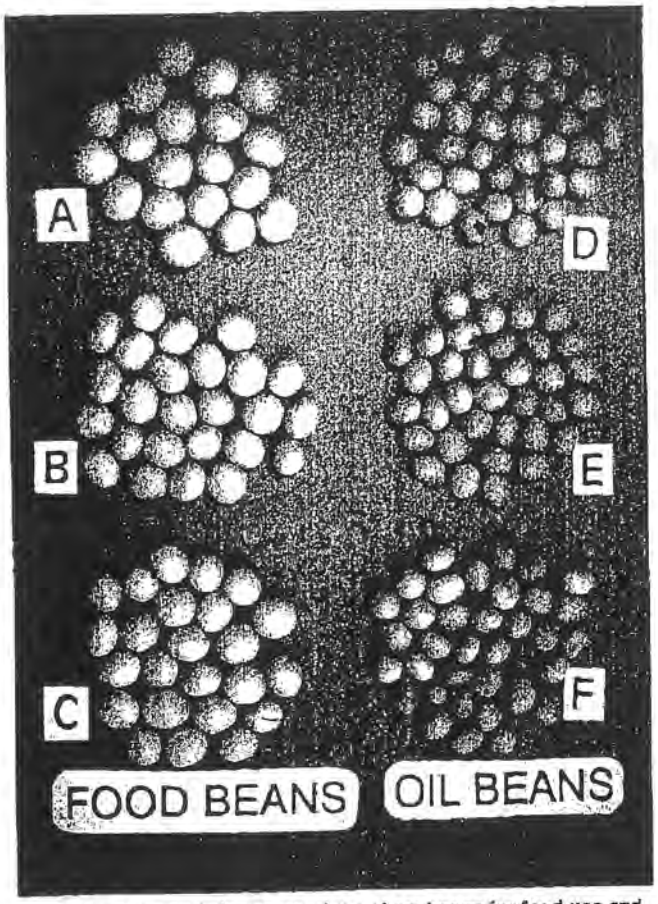

Figure 1. Color and size comparison of soybeans for food use and those intended for crushing

Most everyone is aware of the success of soybeans as a field crop. U.S. farmers produce more than 40% of the world's total soybean production (Table 1) (1). Most of those soybeans are used for food oil and feed meal production. U.S. food uses of the soybean traditionally have been limited to production of soy flours, soy protein concentrates and soy protein isolates.

But more than one-third of U.S. soybeans are exported, with almost half of these exports going to Japan, China (Taiwan) and South Korea (Table 2) (1). In Asia, soybeans often are used for preparing traditional Oriental soyfoods as well as for crushing to produce oil and meal. A different type of soybean has emerged, based on such exports, and it is now apparent that U.S. farmers are growing two types of soybeans: oil beans and food beans (Figure 1).

Food beans vs. oil beans

Oil/meal beans include all the commonly produced soybeans. The major quality issues in such soybeans are oil content, protein, fiber and foreign material. Industry economics are determined by oil yields and the protein level in extracted meal. Because of its beany flavor, limited functionality and an undesirable image, the vast majority of the defatted meal is used as animal feed. Soy meal intended for production of traditional soy proteins may have a higher minimum protein content (50% dry weight basis vs. 44–48% for feed meal soy protein), reduced heat damage and less foreign material. The oil from the crushing of soybeans is used almost entirely for food.

The new varieties of food soybeans, on the other hand, generally are exported to countries in the Far East for preparation of Oriental soyfoods. These raw beans have been bred and selected for specific attributes (Table 3). Their quality is measured by such attributes as a clear or buff hilum, larger seed size, higher protein content, and greater seed integrity. Soybeans shipped for such uses do not include soybeans that are simply larger beans selected from traditional oil/meal beans. In addition to their use in the preparation of traditional soyfoods, the new food-grade varieties,


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Table 1
Estimated world soybean production by major producing countries and all others between 1993–1994 (Ref. 1)

Countries	Million metric tons
United States	49.2
Brazil	23.8
China	13.0
Argentina	12.2
India	4.5
Other	10.3
Total	113.0

Table 2
Estimated U.S. soybean exports by country or region of destination in 1993 (Ref. 1)

Country or region of destination	Volume of exports (thousand metric tons)
Asia	
Japan	4,051
China (Taiwan)	2,335
Korea	1,011
Other	855
Total	8,252
Europe and former Soviet Union	7,953
North America	2,339
Middle East	481
South America	208
Africa	111
Australia and Oceania	80
Grand total	19,424

particularly those with high protein content, have been promoted in preparation of toasted full-fat flour, defatted flour, and for use in preparing soy protein concentrates and isolates. The result has been improved soyfoods as well as soy ingredients.

Traditional soyfoods

Whole-bean soyfoods may be divided roughly into two classes: nonfermented and fermented soyfoods. The nonfermented soyfoods include soymilk, tofu, toasted soy powder and bean sprouts. The fermented soyfoods include soy sauce, miso, tempeh and natto (2,3).

• *Soymilk.* Soymilk is thought to have been made first in China during the second century B.C. It has been consumed since throughout Eastern Asia in much the same way as dairy milk has been consumed in the West. Soymilk was first introduced into the United States around 1930 by John H. Kellogg, the founder of the Kellogg Company. It has been popular among those who are interested in natural, health and diet foods.

Table 3
A general comparison of two types of soybeans: food and oil beans

Attributes	Food beans	Oil beans
Seed size	Large	Small to large
Seed uniformity	High	No preference
Hull color	White-yellow	Yellow
Hull quality	Thin, firm	No preference
Hilum color	Clear to buff	Clear to blank
Protein content	High	Medium to high
Oil content	Low to high	High
Cleanliness	U.S. Grade 1 or better	Any grade
Major application	Tofu, soymilk	Oil, defatted meal

Table 4
Comparison of nutritional quality among soymilk, dairy milk and human milk (Ref. 4)

Components	Unit	Soymilk	Dairy milk	Human milk
Water	g	88.6	88.6	88.6
Calories		52	59	62
Protein	g	4.4	2.9	1.4
Fat	g	2.5	3.3	3.1
Carbohydrates	g	3.8	4.5	7.2
Ash	g	0.6	0.7	0.2
Calcium	mg	18.5	100	35
Sodium	mg	2.5	36	15
Phosphorus	mg	60.3	90	25
Iron	mg	1.5	0.1	0.2
Vitamin B_1	mg	0.04	0.04	0.02
Vitamin B_2	mg	0.02	0.15	0.03
Niacin	mg	0.62	0.2	0.2

Soymilk compares favorably to dairy or human milk in terms of nutrition (Table 4). It serves as a practical source of high-quality and essential nutrients for infants, growing children and adults of all ages. Further, for those who are allergic to, or have problems digesting, dairy milk (lactose intolerance), soymilk offers an alternative.

There are several methods to prepare soymilk from raw soybeans, but the differences are slight (5). A traditional Chinese method is outlined in the diagram shown in Figure 2. After boiling for about ten minutes, the milk is ready to serve. If it is to be served chilled, the milk is bottled and allowed to cool and then refrigerated. The milk also may be sweetened or seasoned. Soymilk has a characteristic flavor that is improved by heating beans prior to or during grinding to inactivate enzymes that catalyze oxidative reactions.

• *Tofu.* Tofu is an inexpensive, versatile, high-protein food made directly from soybeans. Throughout East Asia, tofu has been the most popular way to serve soybeans as a food. Tofu resembles a soft white cheese or a very firm yogurt. Unlike most other protein foods, tofu is free of cholesterol and low in fat, especially saturated fats. The quality of protein in tofu is as high as that found in chicken, but tofu contains fewer calories, 72 per 100-gram serving. Although the United States has discovered tofu only recently, some have predicted that it will revolutionize the U.S. diet.

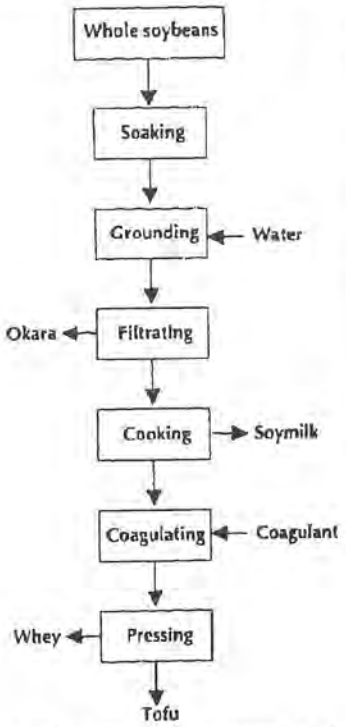

Figure 2. Flow diagram for preparation of soymilk and tofu

Traditionally, there are three main steps for making tofu (Fig. 2): preparation of soymilk, coagulation of soy protein and formation of tofu in a mold. The coagulation step is the most significant since it affects the yield and texture of the final product. There are many factors that affect coagulation, including type and concentration of coagulants, coagulation temperature, and even the method of mixing the coagulant with soymilk (6). The five most commonly used coagulants are magnesium chloride, magnesium sulfate, calcium chloride, calcium sulfate and glucono-d-lactone. After coagulation, tofu is formed into a mold by pressing, similar to how cheese is prepared. The flavor of tofu depends upon the quality of soybeans used. If oil/meal beans are used to produce tofu, the flavor is often "painty." Whole-food beans give a much less pronounced flavor, approaching total blandness.

• *Toasted full-fat soy flour.* Traditionally, toasted whole-soybean flour is made by first toasting beans until they become brown and then grinding the toasted bean to pass through a fine sieve (2). The end product is a brownish flour with a characteristic toasted flavor that is very similar to roasted peanuts.

Such toasted flour often is used as a seasoning. For example, in the Orient the powder is used by sprinkling it on cooked rice or rice cakes. The powder may also be mixed with plastic fats and sugar and used as a filling or a coating.

• *Soy sprouts.* Soy sprouts are fully germinated soybeans. Usually, soybeans are first soaked in warm water for 2–4 hours, then poured into a container with a drain and covered in a dark room where the temperature is maintained at approximately 23°C. The soybeans are sprayed with water every 5–6 hours to reduce the heat generated during germination. When bean sprouts reach a length of more than 5 cm—usually in about a week—they are washed and dehulled. During sprouting, the vitamin C content increases, the oligosaccha-

	Sulfides	Phytates	Flavonoids	Glucarates	Carotenoids	Coumarins	Mono-terpenes	Tri-terpenes	Lignans	Phenolic acids	Indoles	Isothiocyanates	Phthalides	Polyacetylenes
Garlic	✓						✓	✓		✓				
Green tea			✓	✓		✓				✓				
Soybeans		✓	✓		✓	✓		✓	✓	✓				
Cereal grains		✓	✓	✓	✓	✓		✓		✓				
Cruciferous	✓		✓	✓	✓	✓	✓	✓		✓	✓	✓		
Umbelliferous			✓		✓	✓	✓	✓		✓			✓	✓
Citrus			✓	✓	✓	✓	✓	✓		✓				
Solanaceous			✓	✓	✓	✓	✓	✓		✓				
Cucurbitaceous			✓		✓	✓	✓	✓		✓				
Licorice root			✓			✓		✓		✓				
Flaxseed			✓			✓			✓	✓				

Caragay, A., *Food Technology*, 46:(4): 65–68, 1992.

Figure 3. Qualitative distribution of major food plant phytochemicals. Fourteen classes of phytochemicals are known or believed to possess cancer-preventive properties; they are believed to appear in the greatest abundance in the foods and ingredients included in this diagram.

rides are metabolized and trypsin inhibitors decrease. Sprouts are eaten as a cooked vegetable throughout the year. The product is most popular in South Korea and southern China.

• *Soy sauce.* Soy sauce is a fermented soy product used as a seasoning. Soy sauce is prepared by mixing cooked soy meal with toasted wheat and then fermented with a culture of *Aspergillus oryzae* in a salty brine for up to a year. During fermentation, the proteins in the beans are converted to amino acids, and the carbohydrates are converted to sugar and acids. The end product is a dark liquid with a distinct meaty flavor and salty taste.

• *Miso.* Miso is made in a similar way to soy sauce, except that cooked whole beans are mixed with steamed rice and fermentation takes place after addition of salt and a limited amount of water. This is followed by a year-long aging process. The final product is a dark paste with a distinct flavor.

• *Tempeh.* Tempeh is a savory ancient Indonesian food. In Indonesia, tempeh preparation, a traditional household art, consists of boiling presoaked and dehulled beans for about 30 minutes, inoculating them with a starter culture that contains *Rhizopus oligosporu*, and allowing fermentation for 1–2 days. Tempeh has a chunky texture and a distinctively strong taste resembling mushrooms.

•*Natto.* Natto is a popular fermented soyfood in Japan, particularly in the eastern part of Japan. It is one of the few products in which bacteria predominate during fermentation. Traditionally, natto has been made by inoculating cooked soybeans covered with rice straw in a warm room for a couple of days. Rice straw not only provides the fermentation organism, *B. natto*, but also absorbs unpleasant odors generated during fermentation. In modern natto manufacturing, however, soybeans are soaked and steamed, then inoculated with a pure culture of *Bacillus natto* spore suspension. The beans are packed in a polyethylene bag and incubated at high humidity at approximately 40°C for roughly 20 hours. The final product is obtained by maturation at refrigerator temperatures for 1–2 days. Natto has a characteristic odor, a musty flavor and a slimy appearance.

Soy protein ingredients

When oil/meal soybeans are dehulled and crushed, the resulting protein fraction is defatted soybean meal or flakes. Although soy meal protein content can be as high as 49%, with quality nearly comparable to dairy protein, only a small portion of such soy protein is processed into edible soy protein products, including defatted soy grits and flours, concentrates and isolates. These products serve as food ingredients which are incorporated invisibly into such food items as bakery, dairy, confectionery and meat products (2,3).

• *Soy grits and flours.* The major difference between grits and flours is particle size. Typically, both are produced from extracted soybean meal but may also may include full-fat, enzyme-active or lecithinated

(continued on page 598)

Table 5
Estimated food consumption of soybeans in Japan (Ref. 9)

Soyfood	Soybeans used (metric tons)
Tofu (regular and fried)	504,000
Miso	180,000
Natto	90,000
Dried-frozen tofu	28,000
Soymilk	10,000
Soy sauce[a]	5,000
Others[b]	22,000
Total	839,000

[a] Defatted soy meal for soy sauce is not included.
[b] Other soyfoods include boiled whole soybeans, yuba, roasted soy flour and soy sprouts.

Table 6
Estimated food consumption of soybeans in the United States (Ref. 9)

Soyfood	Soybeans used (metric tons)
Tofu (regular and fried)	9,000
Soymilk	4,000
Others	37,000
Total	50,000

(continued from page 596)

products. Grits are obtained by coarse grinding and screening while flours are prepared by fine grinding to pass through a 100-mesh screen or higher.

• *Soy protein concentrates.* When the soluble carbohydrates, primarily sucrose, raffinose and stachyose, and other minor constituents are extracted and removed from defatted soy meal, the remaining product is soy concentrate. Methods used to produce soy concentrate include using hot water washes, isoelectric extraction or an aqueous ethanol extraction. Soy concentrate contains a minimum of 70% protein on a dry weight basis. Soy concentrates have improved flavor, less color and generally are more functional than the flour products.

• *Soy protein isolates.* These are prepared by removing both the water-soluble carbohydrates and water-insoluble polysaccharides from soy protein. Defatted soy meal is first extracted with dilute alkali. The soluble part is then acidified to precipitate the soy protein. After filtration or centrifugation and washing, the precipitated protein is spray-dried. The end product contains a minimum of 90% protein on a dry weight basis. These are the most functional soy protein products. Functionality is further modified by using selective extraction methods or enzyme modification.

Soyfood nutrition

Soy proteins have long been known to have excellent nutritional value. The more recent news is that soybeans and soy products are being studied as to their capacity to prevent and treat chronic diseases such as cancer and atherosclerosis (7,8). The U.S. National Cancer Institute's five-year "Designer Foods" initiative has recently enlisted soybeans as one of the six most promising foods in cancer prevention (7). Of the 14 major phytochemicals in foods, soybeans contain seven, including phytates, flavonoids, carotenoids, coumarins, tri-terpenes, lignans and phenolic acids (Figure 3, page 596). Although phytochemicals are not classified officially as nutrients, they reportedly affect human health as much as vitamins and minerals do. Some have claimed that the discovery of phytochemical effects on the human body will begin the second golden age of nutrition.

Current size of food bean market

The worldwide market for soybeans used to make soyfoods has been estimated as being at least one million metric tons. This is much less than the market for oil and meal production (9). In Japan about 830,000 metric tons of soybeans are used for preparing soyfoods (Table 5), whereas in the United States, about 50,000 metric tons are used (Table 6). Other major markets include Taiwan, Hong Kong, Korea, Singapore, Malaysia, Thailand, etc.

Despite the fact that soyfoods and soy ingredients are nutritious, even dubbed "the health food of the 90s" by various studies, soybeans are still severely underutilized as a food. In fact, just over one-half of one percent of soy meal is consumed directly in foods in the United States (10). The great majority is used as animal feed.

A major problem with soy's acceptance in the United States is the distinct flavor usually associated with soybeans and their products. The beans themselves have, naturally, a beany flavor. Soymilk, tofu, and some other Oriental soyfoods, although each possesses its own texture and taste, all retain some of the original beany flavor. Even in the highly processed soy protein products, the beany flavor does not disappear completely.

Additionally, soybeans have an image problem, having been viewed historically as animal feed. Improved flavor and development of more desirable food products are required; both may be aided through breeding of new food bean varieties.

Breeding of food beans

Most efforts in traditional soybean breeding or genetic engineering have concentrated on yields, disease resistance, herbicide tolerance, or modification of components. Each is intended to improve the competitive position of producers. Breeders have been slow to address the food bean market for, even though it has a fairly large potential, it is dwarfed by the market for traditional oil/meal soybeans.

One major reason is that, traditionally, plant breeding has been a complex and long-term process taking 5–7 years to complete. For food-grade soybeans, there will be a trade-off in yield or disease resistance to produce beans with the desired attributes. Because of this, some buyers are willing to pay a premium of 5–20% above the base price to producers for food beans. Additionally, there is lack of solid scientific studies that delineate which soybean characteristics are desirable for certain soyfoods; however, this situation is changing. The driving force behind this change is a

steady demand for food beans, focused research into scientific theory about soyfood preparation, and improved collaboration and communication between breeders and food technologists.

Over the past several years, food-bean varieties with high quality have been bred. The difference in appearance is dramatic (Figure 1). Some have a protein content as high as 50% on a dry weight basis; others have a less beany flavor. Still others have seed size as large as 1,500 seeds per pound. Other targets for selection include seed integrity and overall bean appearance. Furthermore, improved color and appearance through selection for white cotyledon tissues produce soymilk that is whiter in color, has less beany flavor, and tastes sweeter compared to soymilk produced from regular soybeans. All these improvements in food beans through breeding are targeted for both Oriental and American tastes.

Conclusions

Significant progress has been made in improving soybeans for food use. Much has been accomplished through trial and error to identify desirable varieties. Few programs relating variety to performance in specific foods have been carried out. There is an optimistic future for food beans brought about by current consumption patterns and renewed emphasis on the healthfulness of soyfoods.

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