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UNDERSTANDING SOYBEAN PRODUCTS AND PROCESSING

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PREFACE

This paper is one of a series published by Volunteers in Technical Assistance to provide an introduction to specific state-of-the-art technologies of interest to people in developing countries. The papers are intended to be used as guidelines to help people choose technologies that are suitable to their situations. They are not intended to provide construction or implementation details. People are urged to contact VITA or a similar organization for further information and technical assistance if they find that a particular technology seems to meet their needs.

The papers in the series were written, reviewed, and illustrated almost entirely by VITA Volunteer technical experts on a purely voluntary basis. Some 500 volunteers were involved in the production of the first 100 titles issued, contributing approximately 5,000 hours of their time. VITA staff included Patrice Matthews and Suzanne Brooks handling typesetting and layout, and Margaret Crouch as senior editor and project manager. VITA Volunteer Dr. R. R. Ronkin, retired from the National Science Foundation, lent his invaluable perspective, as a volunteer, to the compilation of technical reviews, conversations with contributing writers, editing, and in a variety of other ways.

VITA Volunteer Harry E. Snyder, who has a Ph.D. in microbiology from the University of California at Davis, has taught and done research in food science and technology for 30 years. Dr. Snyder has also published a number of books and articles on soybeans and other food related topics. Reviewers Ellen Craft, an agronomist, and Gordon Brockmueller, a farmer, have extensive experience with soybean production. Joanne Hokes' background is in the oilseed processing industry, including both soybeans and peanuts. All three reviewers are long-time VITA Volunteers.

VITA is a private, nonprofit organization that supports people working on technical problems in developing countries. VITA offers information and assistance aimed at helping individuals and groups to select and implement technologies appropriate to their situations. VITA maintains an international Inquiry Service, a specialized documentation center, and a computerized roster of volunteer technical consultants; manages long-term field projects; and publishes a variety of technical manuals and papers.

UNDERSTANDING SOYBEAN PRODUCTS AND PROCESSING

by VITA Volunteer Harry E. Snyder, Ph.D.

1. INTRODUCTION

Soybean Production

Since 1950, soybeans have become a valuable part of the world's food supply and of the systems that produce and deliver food. Production of soybeans has grown rapidly and in 1990 amounted to approximately 100 million metric tons (MMT) annually. This compares with about 500 MMT each for rice and wheat and 800 MMT for coarse grains, predominantly maize.

Soybean production is widespread but is centered in temperate climates. The United States produces about half of the total; the other major producers are Brazil (15 MMT), China (10 MMT), and Argentina (8 MMT). Soybeans contribute about 20 percent (13 MMT) of the total vegetable oil and are the world's main, single source of food oil. Palm oil accounts for 8 MMT and sunflower oil 6 MMT of the world's total.

The flowering of the soybean is sensitive to day length; therefore cultivars (cultivated varieties) must be selected for the latitude in which they will be grown. Poorly chosen cultivars may flower before the plant has grown to sufficient size to maximize yield, or the flowering may be so late that the beans freeze before they are mature.

Types of Soybean Products

The main soybean products in international trade are beans, defatted meal, and crude, degummed oil. The beans are usually purchased for processing to crude oil and meal. The crude oil is further refined to edible oil. The meal is used mainly as animal feed, but can be processed into ingredients for human foods: full-fat flours, concentrates (defatted meals with the soluble sugars removed), and isolates (purified protein containing at least 90 percent protein).

Soy products made for direct human consumption, for example soy milk and soy curd, are normally not traded internationally because of their susceptibility to spoilage, but soy sauce and certain other fermented products are stable and can be shipped internationally.

Composition of Soybeans

The soybean is particularly valuable because both oil and meal are marketable products. About 20 percent of the weight of soybeans is oil and 40 percent is protein. The rest is carbohydrate, moisture, and ash. Properly stored soybeans contain less than 13 percent water.

The oil portion is evenly dispersed throughout the bean in structures called lipid bodies, which are too small to be seen in a light microscope. The oil is similar in composition to other vegetable oils with a high concentration of polyunsaturated fatty acids that are thought to be useful in the diet to protect against coronary heart disease. Extracted oil usually contains 1 to 3 percent of phospholipid or gums, which tend to precipitate on storage of the crude oil. For that reason they are usually removed by washing the oil with water.

Other minor impurities in crude soybean oil that are removed in refining steps are free fatty acids, pigments, and flavor compounds. Since the oil is a liquid at room temperatures, hydrogen is added to the polyunsaturated fatty acids to convert the oil into margarines, shortenings, and other solids.

The defatted meal that remains after oil extraction contains valuable protein that is useful in foods and feeds. The protein products available as soy meal or flour contain 44 percent protein if hulls are added back or 47.5 percent protein without added hulls. For animal feed, the soy meal is normally mixed with other ingredients to give a protein level of about 15 percent in the final ration.

Soy meal is heated not only to remove the extracting solvent, but also to inactivate proteins that may retard animal growth. Trypsin inhibitor is the name of one such protein that has been widely studied and is known to inhibit growth in young animals.

2. PROCESSING OF SOYBEANS

Oil Removal by Solvent Extraction

This discussion will emphasize the predominant products and processes of commercial importance. The main oil removal process is solvent extraction. It yields a complete oil removal (less than 1 percent oil remaining in the meal) and gives a meal that has not been heat damaged. Solvent-extraction plants can process 500 to 4,000 tons per day.

The conditions under which beans are stored greatly influences the quality of oil that may later be extracted from them. To ensure oil quality the needed storage conditions are as follows:

1) Moisture content: 13 percent or less to prevent mold growth. However, very dry beans tend to split when being transferred, and the splitting lowers the oil quality.

2) Temperature: as low as feasible to minimize mold growth.

3) Cleanliness: insects or other contaminants can provide moisture to start deterioration, which leads to increased temperature, further increases in moisture, and spoilage.

To prepare soybeans for solvent extraction they are cracked into several pieces and the hulls are removed by blowing air. Hulls, which make up about 8 percent of the weight of beans, do not contain oil and are separated to gain space in the extractors for the oil-bearing tissue. The cracked pieces are conditioned by steam to give a moisture content of about 10 percent at 170 [degrees] F (77 [degrees] C). The conditioned pieces are turned into flakes at this temperature by putting them between smooth rollers. A flake thickness of 0.01 inch (0.025 cm) favors rapid solvent extraction. Thinner flakes extract even more rapidly but also tend to break into fine particles that clog the beds and cause solvent to cut channels through the flakes instead of flowing smoothly through them.

The flakes are conveyed to extractors. These exist in many different forms, but all use beds of flakes 1 to 3 feet (30 cm to 90 cm) deep. The solvent, commercial hexane with a boiling point of about 145 [degrees] F (64 [degrees] C), is pumped over the flake beds so that the flakes entering the extractor are contacted by solvent that already contains oil, while the flakes leaving the extractor are contacted by fresh solvent.

A newer procedure for preparing flakes for extraction puts them through an extruder (or enhancer) to form pellets. Pellets are easier to extract and hold less solvent than flakes, making extraction more efficient.

After extraction the hexane is recovered from the oil and from the meal and reused. Since the hexane is extremely flammable, solvent extraction plants must be designed to minimize chances of sparks or open flames. Equipment is designed to minimize loss of hexane for both safety and economic concerns. The solvent is recovered in heat exchangers or flushed away by bubbling steam through the product.

Solvent is removed from the defatted flakes by steam injection in a device called a desolventizer-toaster, which also heats the flakes to inactivate compounds such as trypsin inhibitor. The flakes are then cooled and ground to the correct particle size for feed mixing.

Oil Removal Without Solvent

The earliest techniques for recovering oil from oilseeds involved pressing the seed with devices that used levers or screws. Later, hydraulic presses replaced the mechanical presses. Today's most efficient way to press oil uses an expeller, a screw-shaped device rotating within a horizontal, heavy-steel, cylindrical cage. As the oilseeds enter at one end of the cylinder, they are subjected to high pressures between the rotating screw and the stationary cage. The pressure forces oil through openings in the cage, while the residual press cake is carried horizontally in the direction of the shaft and is discharged at the other end of the cylinder.

Expellers work best with oilseeds containing 40 percent oil or more, but are less effective with soybeans, from which only three-fourths of the oil is recovered by their use. Nevertheless, expellers have great versatility and are the best method if many different kinds of oilseeds are being crushed. Expellers are free of the many safety problems involved in solvent extraction. Capacities of individual expellers are much less than for solvent extraction plants, with the biggest expellers handling about 60 tons/day. One can choose from a wide range of sizes of expellers to fit the capacity of the crushing operation.

Soybeans need to be prepared for treatment by expellers much the same as for treatment by solvent extraction. They should be cleaned, cracked, and flaked for the greatest oil yield.

The meal obtained from expellers contains more residual oil than from solvent extraction and therefore has a tendency to become rancid. Highly rancid meal can be dangerous for animal feeding because the hydroperoxide content makes the meal toxic. Another problem with the meal is that considerable heat is generated during expelling. If the meal is scorched by the heat, its nutritive

value may be decreased.

Oil Refining

Crude soybean oil, whether from solvent extraction or expellers, is refined to convert it to a high quality, edible oil. The minor components in crude soybean oil that are removed during refining are gums (phospholipids or lecithin), free fatty acids, pigments, and flavor compounds.

The gums are removed because they are insoluble in the oil and gradually precipitate out of the oil during storage. The precipitated material ("foots") is viscous and difficult to remove from storage tanks or ship bottoms, and so it is often removed at the crushing plant before the crude oil is shipped to a refinery. The recovered gum or lecithin is a valuable by-product and is used by the food industry as an emulsifier and anti-sticking agent.

The gums are removed by washing oil with water. About 1 to 2 percent water is added to the oil, and after a thorough mixing, the oil and water are separated by centrifuging. The gums come out with the water phase, but some oil is lost as well. Also, the oil has to be dried after degumming to remove traces of water. If the gums are not recovered for resale as lecithin, they may be added to soybean meal to increase its caloric value.

Free fatty acids are removed because they lower the temperature at which heated oil begins to smoke. Smoking oil is undesirable for cooking.) To remove free fatty acids, the oil is washed with

a dilute lye (sodium hydroxide or potassium hydroxide) solution. The lye changes the fatty acids to soaps, and they are removed in the lye solution by centrifuging. The fatty acids may be recovered for soap manufacture, or they may be added to meal. Sometimes both gums and free fatty acids are removed in a single washing with dilute lye.

Excessive pigments in the oil do no harm, but the oil darkens with repeated heating. Dark oil is considered of low quality, and manufacturers find that light colored oil sells better than dark colored oil. Pigments (and remaining traces of gums, free fatty acids, and minerals) can be removed by bleaching, which is done by adding specially mined clays to the oil. The clays adsorb the unwanted materials and are separated from the treated oil by filtration. Valuable oil is adsorbed along with the unwanted materials, but normally recovery of the oil is not cost effective. The bleaching clay is discarded after one treatment.

The distinctive flavors of such oils as olive, peanut, or sesame are desirable. The distinctive flavor of soybean oil is not desirable, and so the flavors are removed to produce as bland an oil as possible. Flavor compounds are difficult to remove, and the only effective means is high temperature (500 [degrees] F/260 [degrees] C) steam distillation under vacuum, a process is called deodorization.

Other processes for making soybean oil more useful as food include hydrogenation to convert the oil to a solid for use as a shortening or margarine, and winterization to prevent crystals of fat from forming when the oil is chilled.

Soybean Concentrates and Isolates

Because the protein of soybeans is nutritious and easily available in high concentrations, people have sought ways to incorporate it into human diets. Full-fat or defatted flours as starting materials contain the soluble carbohydrates that are naturally present in soybeans. Some of the sugars (raffinose and stachyose) are not digested and absorbed but are fermented by microorganisms in the gut, a process that causes distressing intestinal upsets. Consequently, processes have been developed to remove the soluble sugars while concentrating the proteins. Removal of soluble sugars from defatted flours gives a concentrate with 70 percent soybean protein. Removal of all carbohydrate from defatted flours gives a product with more than 90 percent soybean protein.

Concentrates are produced by making the protein portion of the flour insoluble in water and then extracting the soluble carbohydrates with water or water-alcohol mixtures. The protein can be made insoluble in water by extracting flours that have been heated in the desolventizer-toaster and using hot water--150 to 200 [degrees] F (66 to 93 [degrees] C)--for the extraction. Alternatively, flours that have been desolventized under vacuum to maintain protein solubility can be extracted with water-alcohol (60 to 80 percent ethanol) mixtures or at a pH of 4.5 to remove soluble sugars.

The resulting protein concentrates have varying degrees of protein solubility. Protein solubility is measured by a nitrogen solubility index (NSI) or a protein dispersibility index (PDI). The higher the NSI or PDI the more soluble the protein. For example, concentrates produced by hot-water leaching have low NSIs of about 5, while concentrates produced by low-pH leaching have high NSIs of about 70. High solubility would be useful if the concentrate were to be used in a high protein drink, whereas use in weaning food may not require high solubility.

Soy-protein isolates are produced by extracting defatted flours, which have been desolventized under vacuum to maintain protein solubility, with dilute alkali. The protein solution is then precipitated by adding acid and the protein curd is recovered. If the protein curd is washed with alkali to remove the acid, the protein will become soluble, or the curd may be washed with water and dried as an insoluble protein isolate.

Many uses have been found for soybean concentrates and isolates in the human diet. They may be mixed with other foods to take advantage of the protein that they contribute, for its nutritional value or its improvement of the texture or solubility of the mixture. They may be used in infant foods or formulas for their nutritional value. Also, concentrates and isolates can be texturized by putting a suspension of the protein through an extruder. The extruded proteins have chewy textures that can simulate meats and cheeses when modified with flavors and colors.

One problem with concentrates and isolates that has not been solved is an off-flavor that resembles the raw soybean. Apparently, lipid oxidation (rancidity) occurs during solvent extraction of the oil. The oxidized compounds combine with the protein and their flavors are very difficult to remove.

Nonfermented Soybean Products

Although most soybeans are utilized as oil and meal as described above, there is a wide range of other soybean products. These are mainly the soybean foods traditional in many parts of eastern Asia. Their production may sometimes involve microbial fermentation. Some products that do not require fermentation are described below.

Soy Sprouts. Soy sprouts may be eaten as a cooked vegetable throughout the year. They are used in soups, salads, and side dishes. During sprouting the galactose-containing sugars (raffinose and stachyose) are metabolized by the soy plant; their disappearance reduces flatulence problems among consumers and produces Vitamin C.

The dry beans are soaked in water (12 hours is usually sufficient) and placed in a covered container in the dark. The container must have a drain. The beans are sprinkled with water periodically to keep them cool and moist, but they should not be submerged.

After five to ten days (depending on the temperature), the sprouts will have reached two inches (5 cm) in length and are ready to be cooked. Soybean sprouts are a fresh product and must be eaten soon after production or they will spoil. As with any fresh product, refrigeration may retard spoilage for a week or two.

Fresh, uncooked soy sprouts have an intense beany flavor due to enzyme activity. Boiling or steaming the beans for two to four minutes will inhibit the enzyme activity, minimize the beany flavor, and still retain a crisp texture in the sprouts.

Soy milk. Presoaked soybeans are ground with water and filtered; the water extract is known as soy milk. As with soy sprouts there is an intense beany flavor that can be minimized by heating either before or after filtering. The soy milk may be consumed cold or hot and may be flavored in many ways.

The basic process outlined above may be modified to increase yield, to minimize off-flavors, and to increase efficiency of the extraction process. There are several companies now producing soy milk on a large scale for sale in Asian countries. The final product may be handled by pasteurization and refrigeration in bottles much the same as cow's milk, or it may be sterilized and aseptically packaged in cartons.

The material remaining after soy milk extraction (soy pulp or okara) is just as nutritious as the soy milk but is difficult to market in a palatable form. When generated in large quantities by commercial plants, the soy pulp is often sold for animal feed.

Soy milk compares favorably with cow's milk in nutrients. The fat content is less in soy milk and contains less saturated fat.

There is no lactose in soy milk to cause problems for those people who are lactose intolerant, but the raffinose and stachyose sugars can have similar effects. Soy milk protein lacks enough of the essential amino acid methionine to satisfy rats in feeding experiments, but seems to nourish human infants well.

Soy Curd. A protein-fat curd can be precipitated from soy milk by treating it with calcium salts. This curd is analogous to the curd that can be separated from cow's milk and used in cheese manufacture. The soy curd (known as tofu) is used in soups,, cooked with meat and vegetables, or eaten with special seasoning.

The process for producing soy curd starts with soy milk. Calcium sulfate is dissolved in water and stirred into the hot soymilk (158 to 176 [degrees] F, 70 to 80 [degrees] C). A curd forms, and after it settles,
the fluid is poured off and the curd is pressed to remove excess fluid. Moisture content of the final curd is about 85 percent.

Depending on the process, soy curds of varying textures may be produced. A very soft texture may be achieved by using concentrated soy milk and just enough coagulant to gel the whole mass.
In this case no pressing is used.

The final curd may be fried, dried, or frozen to produce a variety of products with different textures and keeping qualities.
The usual fresh soy curd has a very short shelf-life, which can be extended by refrigeration. If the soy curd is pasteurized and refrigerated, it has a shelf-life of about one week.

Fermented Soybean Products

Soy Sauce. The process for making soy sauce is more complicated and time consuming than for the fresh soybean products. The raw materials are usually a mixture of defatted soy flakes and roasted wheat. These materials are inoculated with pure mold cultures Aspergillus oryzae or Aspergillus sojae); with strong aeration the mold grows rapidly. In about three days at 86 [degrees] F (30 [degrees] C), the greenish-yellow material is harvested. This is the starter culture (koji) that provides enzymes for carbohydrate and protein breakdown during the fermentation.

The starter mixture is placed in brine containing 17 to 18 percent sodium chloride and may be inoculated with bacterial and yeast cultures. The fermentation tanks are deep to encourage anaerobic fermentation, which takes six to eight months.

To finish the process the fermented mash is filtered to produce raw soy sauce and a press cake. The raw soy sauce is heated to 158 to 176 [degrees] F (70 to 80 [degrees] C), which develops flavor and aroma, inactivates enzymes, and pasteurizes the product. A final filtration removes any precipitated substances, and the soy sauce is bottled and sold.

Soy sauce is a dark brown liquid used primarily as a condiment. It has a salty taste and meaty flavor due to a high content of

aspartic and glutamic acids (as monosodium glutamate).

Soy Paste. Originally soy paste or miso was the press cake remaining after removal of liquid soy sauce and was recovered as a condiment. Now soy paste in produced in a separate fermentation. Usually a rice- or barley-based starter culture is used. The starter is added to cooked whole soybean mash. After adding salt and moisture, the mixture is fermented for one to three months.

The final product is achieved by pressing and pasteurizing the soy paste. This condiment can be used as a base for soups or as a seasoning for meats and vegetables. There are many different types of soy paste depending on differences in starting materials, fermentation times, and added ingredients; for example, red peppers.

Fermented Whole Soybeans. Two soybean products fit into this category: tempeh from Indonesia and Malaysia, and natto from Japan.

Tempeh production starts with water-soaked, dehulled soybeans that are boiled for 30 minutes, drained, and surface dried. The batch is fermented with the sold Rhizopus oligosporus using a starter culture from a previous batch. The inoculated beans are wrapped to provide a humid enrironment; banana leaves were used originally as wrappers, but plastic is equally effective. Aerobic growth of the mold continues for 1 or 2 days, until the mass of beans is bound together by the white mycelium of the mold. The brief fermentation does not protect tempeh from spoiling, and it should be handled as a fresh product.

Tempeh can be baked, or sliced and fried in coconut or other oil. It is frequently consumed in soups or as a side dish with a main meal and is also popular as a snack.

Natto is similar to tempeh in that it is a whole-bean product subjected to a brief fermentation primarily for flavor and texture development. Natto production also starts with presoaked soybeans that are cooked until tender. After draining and cooling, the soybeans are inoculated with Bacillus natto, an aerobic bacterium, and incubated in a quite warm environment (104 to 109 [degrees] F, 40 to 43 [degrees] C) for 12 to 20 hours. The bacteria produce a
sticky polymer from glutamic acid that binds the soybeans together, and produce a characteristic musty flavor.

Natto is essentially a fresh product and must be consumed soon after production, but it can be preserved by drying.

Food Mixtures. Soybean protein has an amino-acid composition that complements the protein of cereal grains. Thus a mixture of soybeans with wheat or maize provides protein nutrition for humans that is superior to soybeans, wheat, or maize eaten alone. This fact has been recognized in many cultures, where combinations of beans and cereals are traditional foods.

The realization that high quality protein mixtures can be prepared from relatively low-priced vegetable proteins has led to a variety of products. These vegetable protein mixtures were often developed in government or private laboratories for use by those who had difficulty in obtaining a nutritious diet. Names and countries of origin of some of these products are: Incaparina (Guatemala), Faffa (Ethiopia), Maisoy (Bolivia), and Pro Nutro South Africa). Although the products are very nutritious (often they are supplemented with vitamins and minerals) and can be produced relatively cheaply, they have not become popular foods. Probably, problems with flavors and textures as well as the perception of being "poor people's food" are responsible in part for the low acceptance of these nutritious protein foods.

The U.S. government has developed a series of products based on the concept of a cheap but nutritious vegetable protein mixture. Corn-soy milk (CSM) and wheat-soy blend (WSB) are two examples. These food products are used as donated foods for famine relief or disaster relief.

A final example of a mixture of soybeans with wheat to improve nutrition is composite flour. As low-income nations have improved economically, some have dramatically increased their wheat imports. The wheat is used primarily for various breads and baked goods, which are popular foods worldwide. Wheat alone does not provide nutritious protein, and the wheat flour can be improved nutritionally by addition of soybean flour.

However, the addition of soybean flour must be carefully controlled, as it decreases the desirable bread-making attributes of wheat flour. Breads made with soybean supplemented flours tend to have lower loaf volumes and to be more dense than those made with wheat flour alone. Research has shown that soybean flour added to wheat flour in amounts up to about 12 percent greatly improve protein nutrition without adverse effects. Loaf volume can be improved by adding such emulsifiers as calcium (or sodium) stearoyl lactylate.

3. ALTERNATIVE OILSEEDS AND PROCESSES

Other Oilseeds Compared with Soybeans

Many oilseeds can be used as alternatives to soybeans for production of edible oil. These include canola, cottonseed, rapeseed, safflower, and sunflower. After oil extraction, the remaining meal is generally useful as an animal feedstuff but may need special treatment to remove or modify harmful substances. The processes for alternative oilseeds are not widely different from those used for soybeans but do vary somewhat. For example, dehulling processes differ depending on the nature of the seed.

Most oilseeds contain more oil than the 20 percent present in soybeans. Consequently, they are difficult to flake. In such cases the meats are put through a press or expeller first to remove a large part of the oil, and then they are solvent extracted to remove as much oil as possible.

Although other oilseeds are known to produce excellent vegetable oil, often in higher yields than from soybeans, the protein products from other oilseeds are generally inferior. The protein concentrates and isolates from soybeans are the only such products commercially available and regularly used in the food supply. Similarly, the foods from soybeans based on traditional Asian products are not duplicated by products from any other oilseed.

Alternative Processes

The only reasonable alternative to solvent extraction of oil from soybeans is the expeller, which has already been discussed.

For various food products produced from soybeans, such as soy milk, tofu, tempeh, soy sauce, etc., the size of the equipment ranges from household size to large commercial units.

Most of the products made from soybeans are extensively processed. It is not often that soybeans themselves are simply cooked and eaten. Some possible reasons are the long time needed to soften soybeans by cooking to make them palatable, the high satiety value due to the oil content, and problems with intestinal distress due to the soluble sugars. Extensive work has been done at the University of Illinois (USA) International Soybean Program to develop palatable soybean products for direct use with a minimum of processing.

Because of the wide range of products and processes covered, this paper gives few details on specific equipment needed, costs of production, or marketing prospects. Other sources are listed in the References.

Probably the best sources of information for starting a soybean processing operation are the people already doing business in one's own locality. Starting on a small scale and basing future decisions on knowledge already gained from experience is recommended.

4. COMMERCIAL TRENDS

In the past 50 years there has been a huge increase in the production of soybeans in the world. At least 90 percent of that increased production has been used to produce food oil and animal feed. Traditional soybean foods, including soy sauce, soy milk, and tofu, have continued to be well accepted but with no large increase in consumption.

There is no reason to believe that these trends are about to change. As people have become more affluent, they have consumed more animal products and more vogetable oils. The soybean is a source of the kinds of foods people will be demanding in the future. Moreover, the relatively low cost of soy protein offers the possibility of global improvement of nutrition.

There will be changes in soybean products and processes. From present efforts, one can predict the future development of 1) processes for efficient and energy-conserving recovery of soybean products; 2) processes to improve the quality of the extracted oil; 3) processes to improve the flavor and functionality of soybean protein products; and 4) new cultivars for specific purposes, through biotechnology coupled with traditional plant-breeding techniques. For example, varieties may be developed with changes in their fatty acid composition to minimize saturated fatty acids. Others may be developed that will yield a superior tofu.

The remarkable versatility and worldwide acceptance of the soybean as a food source is likely to guarantee increased usage for years to come.

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ORGANIZATIONS

See Soya Bluebook 1989 for a complete listing of soybean organizations worldwide.

American Soybean Association, P.O. Box 27300, St. Louis, Missouri 63141. Phone 314-432-1600; FAX 314-567-7642.

Soyfoods Association of North America, P.O. Box 234, Lafayette, California 94549.

SUPPLIERS AND MANUFACTURERS

See Soya Bluebook 1989 for a complete listing of suppliers and manufacturers.

Bean Machines, Inc., 390 Liberty Street, No. 2, San Francisco, California 94114 USA. Phone 415-285-9411.

Takai Tofu and Soymilk Equipment Co., 1-1 Inari, Nonoichi-machi, Ishikawa-ken, 921 Japan.

Tiny Tech Plants Pvt. Ltd., Gondal Road, Rajkot 360002, India.

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