Chapter 25

SUMMARY AND RECOMMENDATIONS

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INTRODUCTION

This Handbook has examined in detail the processing steps involved in producing high-quality, nutritious food products from soybean oil. Not only the processes but also the many different products and their uses have been subjected to careful scrutiny. The result is a Handbook that should be of great practical value to processors, food scientists, nutritionists, and students all over the world. It seems appropriate now to summarize the previous chapters and to examine soybean oil processes and products as a whole, to draw whatever conclusions are feasible, and to make some recommendations for the future.

WHY USE SOYBEAN OIL?

The soybean has an oil content of only about 18-20% compared to many other oilseeds having oil contents of 30-55% and other oil-bearing materials with oil contents of up to 65% (Langstraat, 1976). What then are the reasons for the predominance of soybean oil in U.S. markets and exports as well as world markets?

First of all, soybean oil is one of two major products obtained from soybeans, the other product being high-quality, high-protein meal in wide demand for animal feed. This circumstance has resulted in soybean oil being widely available at a relatively low cost.

Secondly, soybean oil has many desirable characteristics. It has a high content of polyunsaturated fatty acids, considered desirable in modern diets, and specifically of linoleic acid, an essential fatty acid in the human diet. Cholesterol has not been detected in soybean oil, either in
the crude, refined, or hydrogenated forms. Soybean oil, even after refining, has small amounts of tocopherols present that serve as antioxidants and have vitamin E activity.

Thirdly, research by USDA Agricultural Research, universities, and industry has provided the basic information needed for: high-volume production of soybeans; development of quality edible oil products through improved processing, handling, and storage; and development of new industrial materials. Investigations by all three research communities need to be continued in seeking new or improved processes, products, and markets for the ultimate benefit of the consumer and the export trade.

BASIC PROCESSING OPERATIONS AND PRINCIPAL EDIBLE OIL PRODUCTS

In the United States, soybeans typically are converted into crude oil and soybean meal by the solvent extraction process. Crude soybean oil contains a number of impurities that, although not necessarily harmful, must be removed before the oil will be readily accepted by the American consumer as an edible product. The aim of the modern refining process is to remove or inactivate all unwanted substances such as free-fatty acids (FFA), colored compounds, prooxidants and decomposition products, including those compounds contributing to off-odors and flavors. Refining is done with minimum oil loss and without the formation or introduction of any deleterious compounds.

The soybean oil refiner converts crude soybean oil into consumer products by a series of processing operations. For a salad oil, the operations usually are conducted in the following sequence: degumming, alkali refining, bleaching, and deodorization. The product is a clear, brilliant oil with a pleasing, pale color and a bland taste or a very mild flavor. Other products require additional processing.

Degumming is an optional step. Crude oil may be degummed prior to caustic refining for lecithin recovery or to produce for export an oil that will precipitate only a minimal amount of solids during shipment.

All soybean oil presently refined in the United States is processed by the caustic method. This refining method reduces the FFA content to 0.01-0.03%, removes practically all of the phosphatides, and also removes some degree of pigments, tocopherols, sterols, and soluble iron and copper compounds—constituents that are present in relatively small amounts. Quality of the finished oil is highly dependent upon adequacy of the refining step. Soapstock is a byproduct of caustic refining and is a valuable source of fatty acids.

Pretreatment of the crude oil with a small amount of food-grade phosphoric acid (300-1000 ppm, 75% concentration) several hours before alkali refining apparently alters the deleterious iron compounds so they are more completely removed in the refining and bleaching steps.

Ammonia refining, which is of interest for pollution abatement, requires post-caustic refining for adequate phosphorus removal (Pardun, 1979). Ammonia refining by itself was tried and abandoned in the United States because color of the deodorized oil was unacceptable (Sullivan, 1979).

Bleaching removes additional pigments, metallic compounds, residual soaps, and trace amounts of pro-oxidants that were not removed by caustic refining. Acidic earths are generally used for bleaching soybean oil to obtain good chlorophyll removal, without which the finished oil may have a greenish cast.

Deodorization is a high-temperature, high-vacuum, steam distillation process that removes additional flavor and odor compounds, removes some sterols and pigments, and destroys any peroxides that may be present. The product of these operations, when properly done, is a high-quality salad oil.

A dual purpose salad/cooking oil is prepared by a light hydrogenation [to 105-115 iodine value (IV)] of the refined, bleached soybean oil followed by winterization and deodorization. This product displays improved oxidative stability and excellent performance characteristics during use for high-temperature cooking. The solid or stearine fraction separated during winterization is incorporated into shortening base stocks.

For plastic (i.e., semi-solid) shortenings and margarines, the oil is hydrogenated to varying degrees but not winterized. Such shortenings are used in many ways in the preparation of baked and fried foods.

A liquid frying fat of very good stability can be produced by lightly hydrogenating soybean oil to about 105 IV, removing the solids fraction by winterization, further hydrogenating the liquid fraction to 75-85 IV, and removing the solids fraction by a second winterization step.

The purpose and products of each step in the overall refining process, a brief description of each, the usual commercial process method (i.e., batch or continuous), and the approximate temperature to which the oil typically is subjected in each step are outlined in Table 1.

For food oil products, further processing is necessary. Plastic (i.e., semisolid) shortenings are prepared from a base stock consisting of a partially hydrogenated fat and a hard-fat or stearine fraction. The base stock is quickly chilled in a scraped surface heat exchanger and "worked" in a
Extraction. Crude oil and soybean meal. Soybeans are cleaned, cracked, conditioned, and flaked, and the oil is extracted from the flakes with hexane in a continuous process. The hexane is recovered and the meal heat-treated. Max. oil temp. is ca. 250°F (120°C) for ca. 5 min.

Degumming (optional). Crude degummed oil and lecithin sludge which may be dried to give soybean lecithin.

Refining. Once-refined oil and soapstock. Crude oil, degummed oil, or a blend is treated with sufficient 12-18° Be' sodium hydroxide solution to neutralize free fatty acids, plus an excess (usually 0.1% calculated as dry NaOH based on oil weight) to remove color pigments, metallic impurities, and phospholipids. Resultant soapstock is removed by centrifugation. Product oil is water washed to remove residual soaps and vacuum dried. Crude oil pretreatment (optional) with less than 0.1% of phosphoric acid converts nonhydratable to hydratable phosphatides. Max. oil temp. is 190°F (88°C) for up to 30 min.

Bleaching. Refined, bleached oil. Once-refined oil is treated with bleaching earth, usually 0.25-0.50% of the acid-activated type, for 10-20 min at ca. 200°F (93°C) under 26-28 in. Hg vacuum, and then filtered. Batch and continuous systems are used for both bleaching and filtering.

Partial hydrogenation. Product varies from a lightly hydrogenated oil to a hard fat, i.e., a completely hydrogenated oil.

Winterization. Liquid oil and stearine. Partially hydrogenated oil is cooled slowly batchwise with gentle agitation to 45-60°F (7-15°C) to produce crystals amenable to removal by filters designed for batchwise or continuous operation. Max. oil temp. is 95°F (35°C) or ambient storage temperature.
sing step (Evans et al., 1960). Abuse, even when not obvious (sometimes called "hidden oxidation") (Frankel et al., 1961), must, therefore, be avoided.

Precautions that need to be followed can be summarized as follows:
- Limiting atmospheric oxidation by minimizing contact of the oil with air at ambient temperatures and avoiding all contact at very high temperatures, e.g., in the deodorization operation.
- Keeping the process time at elevated temperatures as short as possible.
- Avoiding, removing, and inactivating trace metals (e.g., copper, copper alloys, and, at high temperatures, common iron) having a prooxidant effect.
- Avoiding exposure of the oil to light.

Although these precautions are readily stated, adhering to them in commercial operations is not so simple.

The most critical operation undoubtedly is the deodorization step, because in it soybean oil often is heated to about 500°F (260°C) and held there for 15-40 min. The practices of deaerating the oil at a relatively low temperature to less than 0.1 vol. % dissolved oxygen, of using deodorizers of welded construction and of a design that prevents contact of the hot oil with air, and of cooling the oil to 100-150°F (38-66°C) before exposure to air has improved quality of the finished oil considerably.

Other practices that minimize oxidation of the oil in processing include deaeration of the bleaching earth, stripping steam, and wash water, and strict control of process temperature and time.

Practices to be avoided in transporting or handling the oil include cascading of the oil in air and sucking, whipping, or bubbling air through the oil.

Because the rate of oxidation increases with temperature, a reduction in the process time is helpful, as when continuous rather than batch processing is used for the degumming, refining, bleaching, and deodorizing steps. A secondary benefit of continuous vs. batch processing from the standpoint of both lessened oxidation and potential energy savings occurs when two or more process steps can be integrated so the hot oil is moved directly from one operation to the next without the need for intermediate cooling, storage, and reheating.

**OIL STORAGE**

Soybean oil stores best as crude oil. The refined and bleached (RB) oil is more susceptible to oxidation than at other stages in processing. For this reason, the RB oil is stored only for brief periods. The partially hydrogenated oil is more resistant to oxidation than the RB oil but less so than the crude oil.

The oil is stored in carbon steel, stainless steel, stainless clad, or fiberglass-reinforced polyester tanks. Carbon steel tanks preferably are coated on the interior with an epoxy or polyurethane lacquer.

A number of processors saturate and blanket oil leaving the deodorizer with high-purity nitrogen for protection against oxidation. Nitrogen protection should be considered whenever the oil is to be stored for an extended period or held in the hot, liquid state.

**MATERIALS OF CONSTRUCTION**

Several metals, probably active in the form of metallic soaps or salts, are known prooxidants of vegetable oils. Copper, iron, and manganese in the dissolved state are strong prooxidants at very low concentrations (e.g., copper at 1/10 ppm and iron at 1 ppm). Chlorophyll in the presence of light is also a prooxidant.

At ambient and at relatively low process temperatures, carbon steel is reasonably satisfactory for equipment, valves, etc., when surfaces exposed to the oil have been properly conditioned (see Chapter 16). However, at deodorization temperatures, black iron or mild steel exerts a pronounced prooxidant effect and lowers the quality of the finished oil. For this reason, modern deodorizers have stainless steel (usually type 304) or nickel for surfaces in contact with the hot oil.

**ADDITIVES**

In its native state, soybean oil contains traces of both iron and copper. As oil moves through the extraction plant, the impurities tend to increase. Alkali refining and bleaching reduce their level but do not entirely remove them. For this reason, addition of a metal-inactivating or chelating agent such as citric acid or isopropyl citrate at the deodorization stage, preferably while cooling the oil, helps overcome the prooxidant effect of remaining traces of these metals. Both the oxidative and flavor stabilities of the finished oil are improved. Commercial adoption of this practice has increased the overall quality of the industry's output of soybean oil.

To protect the deodorized oil, antioxidants, usually butylated hydroxyanisole (BHA), butylated hydroxytoluene
Improved oil quality, better process safety, new U.S. and world markets, along with improved process efficiency, energy conservation, and pollution abatement can be achieved only through concerted research efforts in modifying and improving all major processing operations, or in developing viable processing alternatives.

The following specific objectives delineate areas of continuing research needs:

- Steam or physical refining as an alternative to alkali refining.
- Hydrogenation and deodorization techniques that minimize trans isomer formation.
- Development of continuous systems for hydrogenation.
- Techniques for hydrogenation of crude oils (e.g., Hasman, 1979; Ucciani et al., 1979).
- Extraction of oil with nonflammable solvents as alternatives to extraction with hexane.
- Development of tailor-made fats and modification of foods to control fat intake (e.g., Babayan, 1974).
- Enhanced knowledge of nutritional aspects of processed oils and heated fats and oils.
- Improved, safe antioxidant systems, metal scavengers, and emulsifiers.
- Additives that enable use of unhydrogenated soybean oil for deep-fat frying (e.g., Huffaker, 1976; Sherwin, 1978).

INDUSTRIAL MATERIALS

Food uses consume 93-94% of our current soybean oil production. In spite of the low volume industrial usage, soybean oil has a greater diversity of uses in nonfood than food products. The traditional industrial markets include coatings, plasticizers, dimer acids, surfactants, factices, and core binders. Several new derivatives of soybean oil have been developed for the coatings and plasticizer markets, engineering thermoplastics, and special lubricants. These products undoubtedly will receive renewed attention in face of the increasing price of petrochemicals and the fact that soybean oil is a renewable resource.

REFERENCES

See also Eastman Products Publication ZG-207C, Eastman Chemical Products, Inc., Kingsport, Tenn.