Processing and Utilization of By-Products from Soy Oil Processing

J.B. WOERFEL, Gold Kist Inc., Box 249, Marks, MS 38646

ABSTRACT

Crude soybean oil contains a number of materials which must be removed to produce a neutral, bland-flavored and light-colored refined oil. While at times these materials may have been considered waste constituting a disposal problem, they are, in fact, valuable by-products when efficiently recovered and processed. Methods of recovery and processing lecithin, soapstock and deodorizer distillate at the refinery level are reviewed. Process and analytical control are discussed. Some of the important end uses are listed.

SOAPSTOCK

Under NSPA trading rules, soapstock is defined as "the by-product which results from the alkali refining of soybean oil. The contract price is based on 50% TFA. Soapstock containing less than 30% TFA will not be considered merchantable and may be rejected." And, "Acidulated soapstock is the product of the complete acidulation of soapstock, thoroughly settled, and the contract price is based on TFA content of 95%. If the TFA content falls below 85% the product is not merchantable acidulated soapstock and may be rejected."

Caustic refining of soybean oil results in the production of ca. 6% raw soapstock containing ca. 35% total fatty acids (TFA). The exact amount depends on the quality of the oil refined—especially the content of free fatty acids and phosphatides—and the efficiency of refining. Raw soapstock, especially that from miscella refining, may be put back into meal in the desolventizer toaster if the refinery is a part of an extraction plant. The feasibility of shipping raw soapstock to another location is limited by the high water content which increases freight cost and causes the soapstock to ferment quickly. As a result, the initial processing of soapstock is commonly done at the refinery, and the resulting product shipped as acidulated soapstock.

Raw soapstock is somewhat difficult to handle. When the TFA concentration is above 30%, it solidifies readily upon cooling, so it is necessary to have heated tanks and lines to maintain temperatures above 140 F (60 C). While standing in a tank, it may break into two phases with a water layer settling to the bottom. If heated to boiling, it has a pronounced tendency to foam, especially if the soapstock is from nondegummed oil high in phosphatides.

Traditionally, soapstock acidulation has been done as a batch process. Soapstock is charged to a corrosion resistant tank. Wooden tanks fitted with copper or bronze coils are still used, although more recent installations are likely to be Monel metal, Carpenter 20 Cb stainless steel or fiberglass-reinforced plastic (1,2). Typically, sulfuric acid diluted to ca. 10% is added in excess to the soapstock charge and the charge is boiled with sparge steam for 2-4 hr. The tank is then settled and the acid water layer drawn off. The acid oil is water-washed by adding 25-50% water, boiling for a short time and settling thoroughly. After drawing off the water layer, the acidulated soapstock can be stored or shipped in steel tanks. Detailed practices vary considerably from plant to plant and even from charge to charge.

The acid waste water is high in biochemical oxygen demand (BOD) and low in pH. However, when properly treated to adjust the pH and remove immiscible materials, it is readily biodegradable, and does not present a problem in a properly designed treatment facility (3).

If the raw soapstock can be handled promptly, it may be processed directly in a soap kettle where it is completely saponified and purified to make industrial soaps.

Several processes have been developed for continuous acidulation of soapstock. One such process (Fig. 1) which is currently practiced on soapstock from degummed soybean oil has been patented by Bloomberg and Hutchins (4).

A mixture of soapstock and centrifuge flush water is delivered at a controlled rate into an acidulation vessel together with a metered stream of sulfuric acid to bring the pH to 1.5-2.0. The vessel is designed so that the contents are both mixed and heated with sparge steam to ca. 200 F (90 C). The mixture constantly overflows into a settling basin. In the settling basin, the acid oil floats to the top and the acid water settles to the bottom. A series of valves at different levels are provided for drawing off the acid oil. The acid water overflows through a standpipe which maintains the level in the settling basin. This process has been used successfully for several years. It is limited to use on soapstock from oil which has been thoroughly degummed, because even small amounts of gum create emulsions which will not separate.

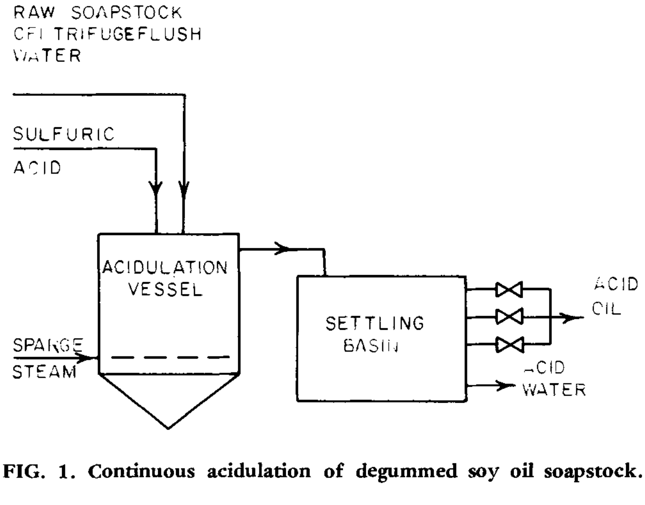

FIG. 1. Continuous acidulation of degummed soy oil soapstock.

De Smet offers a process (Fig. 2) which is made continuous by providing three reactor tanks in parallel. Each tank is charged successively. The sequence of acidulation, water washing and decanting is performed in each vessel. The acid layer from one vessel may be mixed into the soapstock charged to the next vessel to economize on acid usage.

Because acidulation, whether batch or continuous, results in waste water that requires treatment, attention has been directed to other methods which eliminate this source of pollution.

One such method has been developed using a Votator Turba-film processor; this process is illustrated in Figure 3 (5). It consists of acidulation to control pH to 7.0 and evaporation of moisture at 190 mm Hg in a swept-surface evaporator. It is stated that foaming can be controlled by close pH monitoring, proper operating pressure and adjustment of heat exchange conditions. Poultry feeding studies indicated the dried soapstock compared favorably with a commercial feed fat (6).

Figure 4 shows a process for desolventizing miscella soapstocks. In this process, the soapstock is heated and neutralized with sulfuric acid. It is then fed to a multipass, forced-circulation evaporator. Water and hexane are removed as vapor while the soap mass is recirculated through the evaporator at a high flow rate. Finished soapstock is claimed to contain 2.5% water and a maximum of 0.5% hexane, and to be readily pumpable at 140 F (55 C). Water and hexane vapors are condensed, separated by decanting and the hexane returned to the plant system.

Probably the greatest volume usage for acidulated soybean soapstock is in animal feeds. It not only contributes calories to high energy rations, but is an excellent source of polyunsaturates. In animal feeds, it may be used by itself or combined with other refinery by-product fats or tallows and greases. It also is an important raw material for soaps and other industrial products. Industrial soaps find application in cleaning, metal burnishing and polishing, lubrication, mold release and textile dyeing.

Other industrial uses include ore flotation, alkyd resins, foundry products and fatty acid feed stock. Because industrial uses are dependent on fatty acid composition, it is preferred that it be of 100% soy oil origin and not mixed with other types of soapstock.

LECITHIN

Lecithin is the commercial name for a naturally occurring mixture of phospholipids. Lecithin can be derived from egg yolk as well as a number of common oil seeds. However, soybean lecithins are the most common commercial products because they are readily available and have excellent emulsifying properties, color and taste.

Crude soybean lecithin has the approximate composition shown in Table I. About 40% of the total is made up of the three phosphatides and it is apparent that lecithin would have surface active and emulsifying properties. Indeed, it is these properties which give it commercial value.

Only a portion of the phosphatides available in crude soybean oil are processed for lecithin. The greatest part of the available phosphatides are removed with the soapstock in caustic refining of crude oil. Even during degumming, many processors return the gums directly to the meal. In spite of this, soybean lecithin is an important ingredient and an estimated 100,000 tons are consumed each year in foods, drugs and industrial products.

Production of lecithin starts with degumming of crude soybean oil. The gums from the centrifuge are then processed as shown in Figure 5. The preferred dryer is a thin film evaporator operating under a vacuum of less ~~than~~ 25 mm Hg absolute and a temperature of ca. 230 F (110 C). These conditions are designed to reduce moisture to below 1% without damage to the color. The preferred cooler is a scraped wall heat exchanger designed to cool the lecithin to 105 F or below (<40 C).

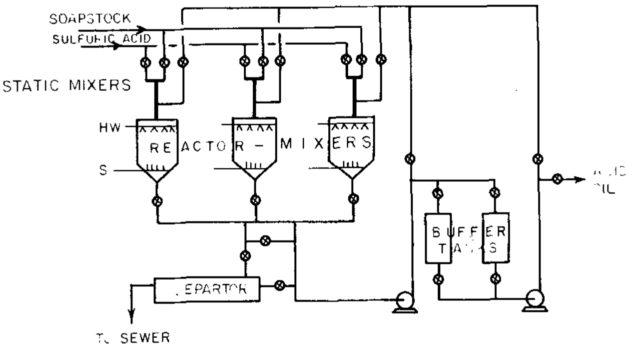

FIG. 2. Continous soapstock acidulation–De Smet.

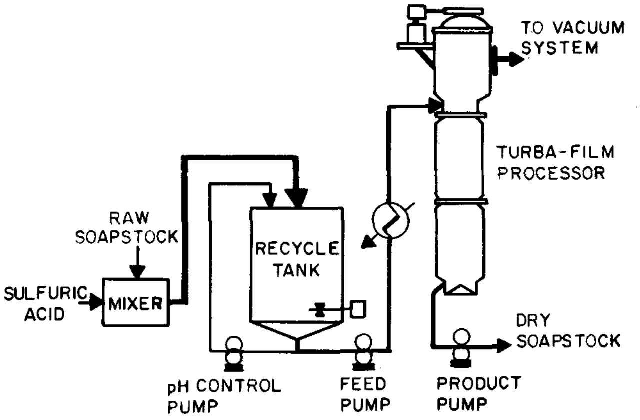

FIG. 3. Soapstock drying–Votator.

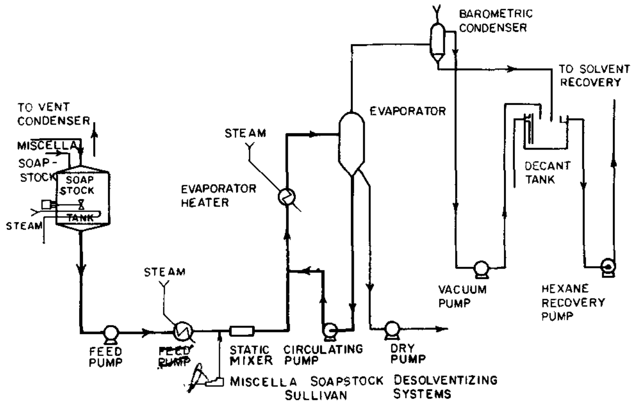

FIG. 4. Soapstock desolventizing systems–Sullivan.

After cooling, the lecithin is collected in water-jacketed, agitated blend tanks where other ingredients are added to meet grade specifications. Soybean oil and soy fatty acid addition control acetone insolubles, acid value and viscosity. Hydrogen peroxide is added as a bleaching agent, either before or after drying.

Even though the lecithin may be bleached, its color is affected by a number of factors in soybean processing. These include quality of the soybeans, cleaning and dehulling practices, extraction depth and temperatures, degumming

TABLE I

Soybean Lecithin Composition (%)

Phosphatidylcholine	16
Phosphatidylethanolamine	14
Inositol phosphatides	10
Misc. (other phosphatides, sugars, sterols, moisture)	25
Soybean oil	35

conditions and lecithin processing conditions.

NSPA rules define six common grades of lecithin as shown in Table II. In addition to these common grades, a variety of chemically or physically modified lecithins is produced for special uses. Acetone fractionation is used to make higher concentrations of phosphatides which may be powdered or granular, and have more neutral taste. Alcohol fractionation increases the choline lecithin fraction and improves emulsifying properties. Hydroxylation using hydrogen peroxide and lactic acid improves o/w emulsifying properties and makes the product more easily dispersable in cold water (7). Table III lists some types of modified lecithin products being marketed in the United States.

Lecithin is widely used in prepared foods as well as in many industrial products. Tables IV-VI list a number of these uses. It is quite apparent that soybean lecithin is one of the significant edible and industrial surface-active agents.

DEODORIZER DISTILLATE

Deodorizer distillate is the volatile organic material which is steam-distilled in the deodorization of fats and oils. This distillate contains tocopherols and sterols which are valuable raw materials for production of natural vitamin E and steroid drugs. The amount of distillate, as well as its composition, depends on the products being deodorized and deodorization conditions. Higher deodorization temperatures and increased sparge steam increase total yields as well as concentrations of tocopherols and sterols. Obviously, one does not operate a deodorizer for the distillate, but to achieve optimal oil quality as measured by flavor, stability and color. In fact, it is undesirable from the standpoint of stability to remove all of the tocopherol. Deodorized soy-

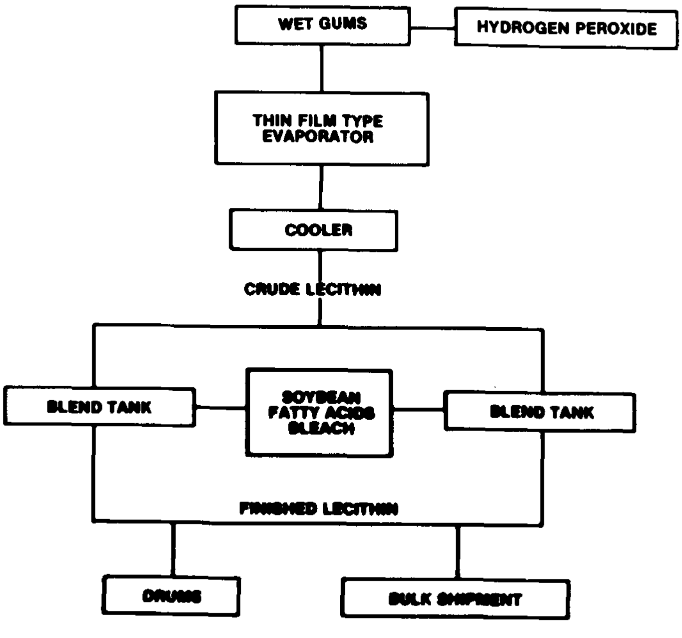

FIG. 5. Process flow lecithin production.

TABLE II

NSPA Soybean Lecithin Specifications

	Fluid (%)	Plastic (%)
Acetone insoluble, min	62	65
Moisture, max	1	1
Benzene Insoluble, max	0.3	0.3
Acid value, max	32	30
Viscosity, 77 F, max	150 PS	
Penetration, max		22 mm
Color–Gardner, max		
Unbleached	10	10
Single-bleached	7	7
Double-bleached	4	4

TABLE III

Specialized Lecithins

Powdered or granular
95% minimum acetone insoluble

Hydroxylated
Hydrogen peroxide-lactic acid treated

In carriers other than soy oil

Combined with other surface active agents and selected carriers

Specially filtered for food supplements

Fluid concentrated 66 + %

TABLE IV

Food Uses of Lecithin

Uses	Typical action
Baking	Modify the gluten characteristics of flour, emulsifier, antioxidant, wetting agent
Candy	Emulsifier
Chewing gum	Softener, retains moisture, retards staling
Chocolate	Reduce viscosity by wetting and dispersing action
Ice cream	Stabilizer, emulsifier
Instant foods	Wetting, dispersing, emulsifying
Margarine	w/o emulsifier, antispattering agent
Pan release	Antisticking agent
Shortening	Emulsifier, dispersant

TABLE V

Industrial Uses of Lecithin

Uses	Typical action
Dyes	Solubilizer, dispersing agent
Insecticide	Oil soluble emulsifier, dispersant
Inks	Grinding aid, solubilizes dyes
Leather	Softening agent, oil penetrant
Latex emulsions	Facilitate pigment dispersion; antisetting agent; prevent agglomeration; emulsion stabilizer; minimize foaming; easy, uniform application without lap marks; freeze-thaw stability
Paints	Aids pigment grinding and dispersion, retards setting, yields maximal color strength and full hiding power
Petroleum	Emulsifier and wetting agent for marine greases, cutting oils
Plastics	Slip agent, mold release, pigment dispersant
Rubber	Pigment dispersant, mold release agent
Textiles	Softening agent, lubricant

TABLE VI

Other Uses of Lecithin

Food supplement	Natural source of phosphatides
Cosmetics	Emulsifier, foam stabilizer, emollient, penetrant, vitamin source, hydrolysis inhibition
Drugs	Emulsifier, suspending agent
Animal feeds (other than pet foods)	Emulsifier, wetting agent, nutrition supplement

TABLE VII

Deodorizer Distillate Composition

	Range	Average
Acid value	40.0 - 50.0	39.7
Unsaponifiable	33.2 - 44.9	38.7
Sterols, total	14.1 - 22.6	18.6
Campesterol	3.2 - 5.2	4.1
Stigmasterol	2.8 - 5.2	4.0
Sitosterol	8.1 - 13.3	10.5
Tocopherol, total	9.0 - 14.7	12.4
Alpha	1.7 - 3.7	2.3
Beta and gamma	5.6 - 8.9	7.7
Delta	1.7 - 3.3	2.5

bean oil may have ca. 1,000 ppm of tocopherol (8,9). Quantities of deodorizer distillate recovered may be from 0.15-0.45% of the oil deodorized.

Table VII shows range of composition from one plant over a year's time. The plant was processing soybean and cottonseed oils, both hydrogenated and unhydrogenated.

At the present value of $3.00/% of tocopherol, deodorizer distillate at 12.4% is worth 37.2 cents/lb which is substantially more than fully refined oil. Considering a yield of 0.28% the return from the distillate is $1.04/1,000 lb of oil deodorized.

Depending on market conditions, the value of distillate may be determined by its sterol, rather than tocopherol, content. It is readily apparent that, with these values, an efficient distillate recovery system is an economically desirable feature of a deodorizer system.

DEODORIZER DISTILLATE RECOVERY SYSTEM

Figure 6 is a schematic flow sheet for an EMI distillate recovery system. Steam and distillate vapors coming from the deodorizer at a pressure of 2-5 mm Hg are compressed to 50-60 mm Hg through one or two booster stages. The vapors pass upward through a packed tower, where they are contacted with liquid distillate cooled to ca. 140 F (60 C) by circulating through a heat exchanger. A level controller in the bottom of the tower maintains a constant volume of condensed distillate in the system; the excess is continuously drawn off.

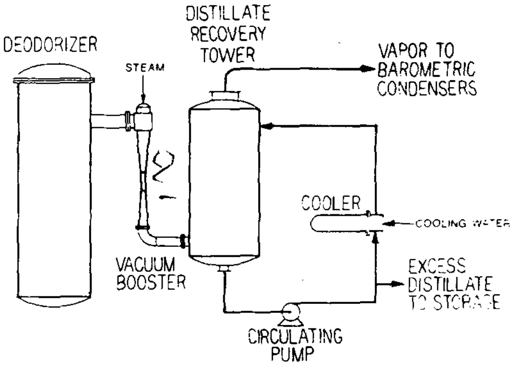

FIG. 6. Deodorizer distillate recovery system.

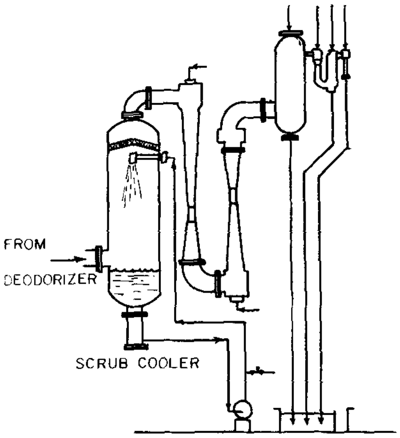

FIG. 7. Deodorizer distillate recovery system.

Packing in the tower is an open grid stainless steel to minimize pressure drop while providing good liquid-vapor contact. Demisters are installed to minimize entrainment losses. It is very important that these be of proper design and kept in place to achieve efficient removal of droplets being carried in the high velocity vapor stream.

Efficiency of the deodorizer distillate removal is quite high. In recent tests, we determined the tocopherols and sterols recovered from the distillate and from the fatty residue in the barometric condenser water. These tests indicated more than 98% recovery of tocopherols and more than 95% recovery of sterols in the deodorizer distillate.

Figure 7 shows a deodorizer distillate recovery system by Elliott. This is similar in principle, but employs a scrub cooler rather than a packer tower. Also, the water cooler is an integral part of the scrub cooler. This sketch also shows that the scrub cooler is located immediately after the deodorizer and before the ejector boosters. This configuration is said to minimize steam consumption to the booster and conserve energy.

Where a distillate recovery system of this type is not installed, the deodorizer distillate is condensed in the barometric cooling water. This distillate may then be recovered as hot-well skimmings. Certain anionic polymers can be used to coagulate and float the greasy material to improve its separation from the water.

Recovery of the distillate as hot-well skimmings is not nearly as satisfactory as recovering it dry, because the skimmings contain a large amount of water which must be removed. Yields of tocopherol may be reduced because of oxidation occurring in the barometric water cooling tower or during the drying.

Deodorizer distillate may be assayed for tocopherols and sterols by gas liquid chromatography (10). The American Oil Chemists' Society method Ce 3-74 calls for a silicone rubber column packing and flame ionization detector.

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