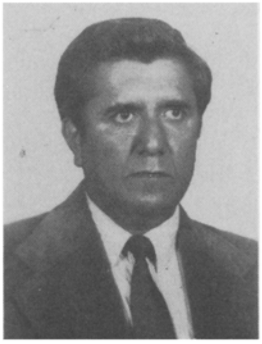

Extraction of Oil from Soybeans

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ABSTRACT

Modern processing plants extract soyabean oil by solvent liquid transfer. Soyabeans are cleaned, cracked, dehulled and conditioned into a thin flake before they enter the extractor. Extraction is by successive, countercurrent washes of hexane solvent. The extracted flakes are then carried by a sealed conveyor to be desolventized in enclosed vessels by application of jacket and sparge steam. Hexane is removed from the oil in rising film evaporators and with final vacuum distillation. Hexane is recovered from the meal and the oil in atmospheric condensers. The complete plant installation is explosion-proof and all equipment is sealed and vapor-proof. For a good operation, soyabeans must be clean, undamaged and at the correct moisture and temperature. Parameters of the process in the plant are: tonnage, hexane loss and energy usage. Oil quality is measured in terms of free fatty acids, absence of residual hexane and crude oil color. Meal quality is determined by residual oil, moisture, protein, urease activity, protein solubility and mesh size in the finished product. Innovations at modern plants include degumming of the oil, lecithin drying and blending and production of soyabean meal with high protein solubility for human consumption.

Oil is extracted from soybeans at modern plants by solvent washing of soybean flakes which have been preconditioned for optimal separation of oil from the soybean meal, using hexane as solvent. The heart of the solvent extraction plant for vegetable oil is the solvent extractor. The equipment and working conditions of an extraction operation complement the function of this piece of equipment and its characteristics represent the engineering ideas of the firm that designed the complete plant.

Before the soybeans are extracted, however, they must be cleaned, cracked and flaked. In order for the extractor to function efficiently, the soybeans must be flaked to a thickness of 10-12 thousandths of one inch. These flakes should have a moisture of 9.5-11.5% and a temperature of 55 C upon reaching the extractor. If these conditions are not maintained, extraction can be erratic because of irregular drainage. Plugging can occur in the equipment, while tonnage drops and hexane loss increases.

The function of the preparation room for solvent extraction is to bring the soybean flakes to the right conditions for optimal extraction at the desired tonnage.

Soybean Cleaning

In the preparation room, soybeans are first cleaned to remove the large and small trash that typifies agricultural products. This generally is done in at least two cleaning steps, using machines which clean the soybeans by sizing and by air aspiration. Of the several grain cleaners manufactured presently, the best cleaning system should be successful in removing trash from soybeans down to 0.5% at the desired tonnage. Also, it should have ample air and conveying capacity to remove the trash into the plant operator's system for collection and tidy disposal. Commercial rules accept up to 5% trash in soybeans. A well equipped plant running 300 tons/day must be equipped to dispose of 13.5 tons of trash every 24 hr during the worst conditions of dirty beans. A more demanding characteristic from good soybean cleaners is that they have an adjustment or provision for salvaging broken soybean kernels. Since broken kernels tend to be lost along with the small trash, a good cleaner is provided with air and screen adjustments to optimize cleaning and not lose broken kernels. However, a plant which must regularly run soybeans with a high percentage of broken kernels should have a system that will direct into a gravity separator all the cleaning fractions containing broken kernels. This is the most successful machine for salvaging commodities of the same size as the trash. It is more successful at low capacities; therefore, it must be designed as a part of the system to handle contaminated fractions to be separated.

Soybeans must be cleaned, because trash contains no oil and clutters equipment space. Trash also must be removed for sanitation, because bacteria is concentrated in it. Sand must be removed in order to prevent excessive wear in all machinery and conveyors, and especially in the cracking and flaking rolls. A good rule for a successful cleaning operation is that ash content of clean beans should be less than 2.5% by the AACC Method 08-16 (1) or the AOCS Bc 5-49 (2). This has no relationship to the ash content as trace minerals (3).

If a soybean extraction plant manufactures soybean flour for human consumption, soybeans must be cleaner and more uniform. The industry has not established this standard definitely, nor has the relationship been established between the ash content of soybeans and the bacteria count in soybean flour resulting from the particular beans analyzed.

Soybean Cracking and Dehulling

In order to produce thin, large soybean flakes in the preparation room, beans must be broken to an exact mesh. They also must be dehulled in order to produce high-protein meal with 48-50% protein as desired. Thus, 3.5-4.5% of the hulls must be removed from the beans.

The first operation to accomplish this is to crack the beans into small pieces. This is done by some type of cracking mill, generally operating in 2 subsequent stages for better efficiency. This mill adjusts to obtain different degrees of cracking. The ideal size for flaking of the cracked beans is between 6 and 10 U.S. mesh. However, larger and smaller pieces always result and because of this, the cracking standard is a compromise. An ideally adjusted mill should produce the fewest large and small pieces outside the ideal size. In reality, a well adjusted mill yields less than 20% larger than 6 U.S. mesh and less than 3% smaller than 20 U.S. mesh. Besides sizing the kernels for flaking, the beans are cracked in order to separate the hulls from the meats by sizing and aspiration in separating machines. This generally is done in 2 or 3 stages, which combine both forms of separation. Almost every separation produces clean meats, clean hulls and middlings or tails. These tails go to a gravity separator where meats are salvaged. Pure hulls subsequently are toasted and ground, then sent to packing and storage. A good separating layout will have adequate capacity and flexibility to yield ca. 3-5% hulls having a maximum of 2.5% total residual oil.

The meats next go to a conditioner for adjusting temperature and moisture for flaking. Flakes must be conditioned to a temperature of 65-70 C and a moisture of 11 ± 0.5%. Kernels are adjusted to this moisture. The temperature in the solvent extractor is kept constant mainly through the temperature of the flakes being fed to it. For this reason, provisions must be made that the flakes reach the extractor at the correct temperature to keep the extractor at 55 C. Provisions include conditioning temperature and conveyor insulation, depending on the type of equipment and the length of run from the flaking rolls to the extractor.

The flaking operation is the single most exact and important function affecting extraction in the plant. Many papers have been written explaining the correct flaking procedures, flaking roll adjustment and alignment, and general maintenance of flaking rolls and feeders to attain production of uniform flakes.

Solvent Extraction

The soybean flakes are transported to the solvent extractor. The extraction plant requires an explosion-proof construction and vapor-tight joints and fittings. For this reason, the preparation room usually is separated or isolated from the extraction plant.

Flakes enter the extractor through a vapor seal which allows the material to enter while keeping hexane vapors from escaping. The solvent extractor at a soybean plant is an enclosed vessel which is designed to wash, drain and extract soybean flakes by percolating subsequent solvent passes to the bed of soybean flakes, while the solvent sprays and the bed of soybeans move relative to each other. The extractor is designed to have the initial solvent run countercurrent to the flakes. Hexane solvent working in the extractor will enter and wash the flakes with the least amount of oil just before they are dumped into the spent flake bin and proceed to the newest material being fed into the extractor, from where the solution of oil and solvent, called miscella, is pumped from the extractor into the evaporating stages.

Miscella and Meal Desolventization

The percolated miscella, after it passes through a bed of material or "basket," is collected in the corresponding pan under the flakes being extracted. From here, it flows by gravity into a pump and is elevated to the top of the extractor in order to reach the next miscella stage through a distribution system, and to have washed the subsequent batch of flakes. This cycle is repeated from the most extracted to the least extracted flakes until all the extractor's miscella stages are completed. Full miscella exits from the last pump to the liquid evaporating section.

Hexane is evaporated from the miscella by heating in tube evaporators and stripping in a final vacuum distillation column. The final oil must pass a negative flash-point test up to 120 C.

The extracted flakes are desolventized in vessels heated by jacket and sparge steam. It is necessary to remove all the hexane in the flakes and to adjust the final moisture to 12 ± 0.5%. Flakes must be heated while maintaining a moisture of ca. 20-22% in the top vessels in order to minimize the urease activity of the meal. The level of urease activity is a test used in the soybean industry to determine if soybean meal has been properly heated during processing and as a measure of the nutritive value of the meal, especially in poultry feed. When soybeans have been properly dehulled, the meal has a final protein content of 48-50% on the basis of 12% moisture.

Meal generally is ground so that 95% passes through a U.S. 10-mesh and so that a maximum of 3% passes through U.S. 80-mesh.

Recovery of Hexane Solvent

The hexane solvent evaporated from the desolventizing of flakes in the desolventizer-toaster and from the miscella in the evaporators is carried by pipes into atmospheric condensers for conversion into liquid to be deposited back into the hexane tank in the plant. The condensers are cooled by water from an open cooling tower system. The hexane vapors from the vacuum system are scrubbed in a condenser and the steam ejector creating the vacuum is discharged into a safety hot water tank which insures that any carry-over traces of hexane will be evaporated from this tank back into the hexane vapors system, and that hexane will not escape into the plant drainage.

The hexane solvent feed tank for the extractor, into which the solvent is recovered, generally is made of 2 sections. In one section, hexane and water are decanted, and another section contains pure hexane. The decanting section is designed to separate hexane from water and dispose of each liquid separately. This separation is necessary because water evaporates and condenses along with the hexane solvent in the plant vapor system. Water is evaporated when the soy flakes and the miscella are heated. Also, some sparge steam goes to the vapor system and is condensed with the hexane.

Vapor-Scrubbing System

Noncondensable gases also are evaporated with the hexane solvent. These gases will not be condensed by cooling and will remain in the vapor system creating pressure. For this reason, the hexane vapor system in an extraction plant is an open system. The final gases are vented into the atmosphere once they are cooled; hexane is then condensed and pressure is lowered. These gases must be scrubbed before they escape into the atmosphere in order to arrest traces of hexane solvent. This is done by a scrubbing system which washes the escaping vapors and dilutes the hexane as it lets the noncondensable vapors escape. The solute containing the vapors is then stripped by heating to recover the hexane in the hexane vapor system. This step is the end of the hexane recovery in a modern solvent plant. Mineral oil pharmacopea-grade is often used in this type of solvent recovery scrubber.

Utilities in Solvent Extraction

An approximation of the utility consumption for the operation of a modern solvent extraction plant follows, based on units/MT of seed capacity/24 hr for the extraction operation only:

Electrical consumption	2.29 KwH/ton capacity
Cooling water	12.35 ℓ/min/ton
Steam saturated 10.5 kg/sq cm	26.14 Kilo/hr/ton

Boiler horsepower	1.67 HP/ton
Water consumption	7.3 ℓ/min/ton not including cooling water make-up
Hexane consumption	3-8 ℓ/ton is manufacturer's guarantee, depending on plant capacity.

These figures are calculated for plants with evaporation economizing and dehulling of beans for production of high-protein meal.

IMPORTANCE OF SOYBEAN OIL IN TODAY'S VEGETABLE OIL CONSUMPTION

According to industry records published by the American Soybean Association, soybeans constitute 53% of the total oilseeds in the world. Soybeans are so important that they outrank their nearest competitor, cottonseed, by a margin of 3.7-1. The total estimated production of oilseeds for the year 1980 is 181,812,000 metric tons.

The expected production of soybeans for this year is 97,596,000 tons. According to the same sources, soybean oil is used in the United States for 80% of salad oils, for 78% of margarines, 75% of cooking oils and 59% of manufactured shortenings.

Modern Innovations at Soybean Extraction Plants

Because gums in crude soybean oil tend to collect at the bottom of storage tanks, partly through the action of residual moisture in the oil, many plants degum the oil at the extraction site. This operation allows the plant to handle degummed oil exclusively, as the degumming operation is incorporated into the extraction area.

As a result, many plants have installed facilities to dehydrate and blend gums to convert them into various types of finished lecithin, thus making available several more finished products at the extraction location.

With the increased interest in the use of soybean meal for direct human consumption, a modern innovation in extraction plants is the installation and operation of special desolventizers with a wide range of protein solubilities for the production of soybean flours. These flours also are ground to several different particle sizes in response to a growing market demand.

These new developments in solvent extraction plants for soybeans, along with the need for increased efficiency and improved product quality, are demanding a higher technical level for personnel operating and directing these plants as the extraction operation becomes more complex.

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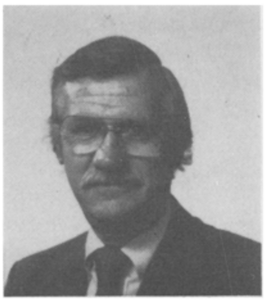

Degumming, Refining and Bleaching Soybean Oil

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ABSTRACT

This subject deals with the removal of the fat-soluble impurities from crude soybean oil. These impurities may be present in true solution or in a colloidal state; their effective removal is necessary to achieve quality standards for end-use products. The processing step options for the removal of these impurities in any given situation are easily defined; the conditions and practices used, however, are the primary concern of this paper. International trading of soybean oil mandates the degumming step. The increased use of import/export soybean oil increases the importance of this processing practice. Pretreatment and effective contact time are the critical issues. Refining, as a specific process, deals primarily with free fatty acid removal, with or without simultaneous degumming as a single-step operation. State-of-the-art wet, chemical refining practices are described, and the current limitations and future opportunities for the physical refining of soybean oil are discussed. The importance of the bleaching step cannot be overstated and it should be noted that color reduction is only coincidentally achieved. The primary function of the bleaching process is to remove oxidative breakdown products, and the degree or level of treatment should be consistent with that objective. Underbleaching and thermal decolorization (deodorization) of soybean oil are misguided practices. Once "cleaned-up" through adequate bleaching, an oil should be guarded against thermal/oxidative abuse.

INTRODUCTION

The emphasis of our subject needs to be turned around and our objective stated as the removal of fat-soluble impurities present in crude soybean oil. These impurities may be present in true solution or in colloidal suspension, and their effective removal is absolutely necessary to achieve the finished soybean oil quality standards for flavor, appearance and stability required by end-use product applications. The unit processes usually associated with this task are degumming or desliming, refining, both chemical and physical, and adsorptive bleaching (1-6).

The soluble impurities in crude soybean oil are identified as gums or sludge which consist of phospholipids, the crude lecithins and metal complexes (notably those of iron, calcium and magnesium), free fatty acids (FFA), peroxides